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GEOLOGICAL SURV

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VOLUME EIGHT

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PREFACE

The present volume is the eighth in the series of general reports issued by the Survey. It consists of three parts dealing respectively with the highway work, the general mineral industries, and a detailed report on a special industry, the lime and cement industry.

The *Second Report on State Highway Construction* by Walter Wilson Crosby constitutes Part I of the volume and discusses in detail the operations of the Highway Division of the Survey for the period from January 1, 1906, to January 1, 1908. This report was issued in March, 1908, and shows that during the period the Division has continued its investigation of the condition of the roads of the State, its testing of road and structural materials, the survey of State properties, and the actual construction of roads under various acts of the Legislature as in former years. The period is also marked by the preparation of a new road map of the State on the scale of three miles to an inch which exceeds in its accuracy and detail any similar map issued by the State.

The report on *Maryland Mineral Industries* 1896-1907, by Wm. Bullock Clark and Edward B. Mathews forms Part II of the volume and was issued in March, 1908. It represents a statistical study of the various mineral industries of the State based upon the information gathered annually by the State Survey during the decade since its organization. The statistics in each case are preceded by a summary of the information regarding the character, distribution and uses of the subject under discussion. A special chapter is devoted to the Maryland coal operations during the year 1907 in which the detailed information regarding Maryland coal mines which was collected in 1902 is revised and brought up to date. A notable feature of this report is the bringing out of the fact that there has been a steady increase in the annual output of Maryland mineral products during the twelve years following the organization of the State Geological Survey. In that period the total value has nearly doubled while

the people directly or indirectly affected have greatly increased in number. Under normal business conditions the valuation of the output of mineral products each year now exceeds $10,000,000. The largest individual industry is that of coal which is followed in turn by those of clay and stone.

The *Report on the Limestones of Maryland,* by Edward B. Mathews and John Sharshall Grasty constitutes Part III of the volume and is devoted especially to their use in the manufacture of lime and cement. This report was issued in March, 1910.

The first part of the report is a general educational summary regarding the uses of limestones for construction, agricultural, and metallurgical purposes, and the manufacture and uses of limes and cements. In the preparation of this report the authors have received the very valuable assistance of Mr. R. K. Meade, of the Meade Testing Laboratories, Allentown, Pennsylvania, who has carefully revised the entire manuscript, and has also added materially to its value by original contributions at various points. The manuscript in an earlier form also received the perusal and kindly criticism of Mr. Charles Catlett, of Staunton, Virginia, and Mr. E. C. Eckel, of Washington, D. C. The report has also been enriched by the discussions of furnace flux and the methods of determining magnesia in the field furnished by Professor J. J. Porter, of the University of Cincinnati.

The second portion of the report, dealing with the lime and cement materials as they occur in Maryland, represents the assembling of information gathered by many different members of the Survey. The whole area under discussion was examined in detail by the authors who have had the assistance of many workers assigned to special regions. The field work of the Piedmont Plateau and the Hagerstown Valley was conducted by Dr. Grasty under the supervision of the senior author. In this work Dr. Grasty received great assistance in the deciphering of the stratigraphy and structure of the Hagerstown and Frederick Valleys from Dr. R. S. Bassler, of the U. S. National Museum, while portions of the areal mapping in this region were entrusted to R. C. Williams who has furnished a structural section across the Hagerstown Valley given on page 407. The report contains over 300 chemical analyses of limestone, 38 of clays and

shales, and 41 of cements. Many of the shale and limestone analyses are new, nearly 250 analyses of recent determination having been incorporated in the report. In this analytical work the Survey has been assisted by Messrs. R. K. Meade, Penniman and Browne, Charles Catlett, J. J. Porter and R. S. Williamson, but the majority of the analyses were made under Survey auspices by Drs. E. G. Zies, M. R. Schmidt, H. P. West, Messrs. O. E. Bransky and W. A. A. Reinhardt.

The results of the areal mapping and the scientific aspects of the limestone bodies of the western Piedmont served as the basis of a dissertation prepared by the junior author. This manuscript together with additional field notes has been utilized by the senior author in the preparation of the present report.

In the treatment of the deposits the State is divided into seven divisions. Each of these is discussed with notes on the geology, a description being given of the exposures and quarries of lime and cement materials. The locations of the individual quarries, and the sources of samples which have been analyzed are represented on the large map showing the areal distribution of the limestones of the State.

The illustrations used in this volume have been secured from various sources, most of them, however, being from photographs taken by the members of the State Geological Survey while individual photographs have been supplied by the various lime and cement companies interested in the work.

The Survey as in former years is indebted to the Director of the U. S. Geological Survey who through his chiefs of division has cooperated at many points with the State organization. This is especially true in the case of the present report with Mr. E. W. Parker, Statistician in Charge of the Division of Mineral Resources.

PART I

SECOND REPORT ON STATE HIGHWAY CONSTRUCTION

BY

WALTER WILSON CROSBY

Chief Engineer

LEGISLATIVE ROAD BELOW BARRELLVILLE, ALLEGANY COUNTY. IMPROVED SECTION ALONG JENNINGS RUN.

SECOND REPORT ON STATE HIGHWAY CONSTRUCTION FOR PERIOD FROM JANUARY 1, 1906 TO JANUARY 1, 1908

BY

WALTER WILSON CROSBY
CHIEF ENGINEER

INTRODUCTORY.

The work of the Highway Division during 1906 and 1907 has included an investigation of the condition of the roads of the State, a study of the paving materials for the towns, the preparation of a new road map of the State, the testing of road and structural materials for the municipalities, and the survey of State properties. The Survey has also frequently furnished to the counties and towns advice and plans for road and street work. Investigations of the available paving materials of the State have been made, and plans are approaching completion for the preparation of a report regarding street pavements for Maryland cities and towns, with remarks on the materials best adapted for the purpose and the methods to be pursued in their utilization. Such a report cannot fail to be of great practical value in securing better results in the cities and towns of the State.

Reference has already been made, in an earlier statement regarding Topographic Surveys, to the preparation of a new State map. The Highway Division has coöperated in the preparation of this map and has used the same to designate those highways which it considers could be desirably improved under the present or future acts of the General Assembly. By the use of symbols the roads already built by the State Commission, the existing turnpikes, and a suggested system of improved

highways are shown. It is believed that this new and up-to-date map will prove of much value to the people of the State in their efforts to devise a modern road system.

Since the passage of the so-called "Shoemaker Law," the counties of the State, which before its enactment had attempted some permanent improvement annually and had called on this office for advice and assistance, have devoted their annual improvement funds to work under the "Shoemaker Law," realizing that it was possible to obtain even better results from this source than they could formerly. By so doing, they have been able to secure greater assistance from this office in the way of more detailed plans and more constant supervision of the work, and it has also been possible for them to secure far more extensive improvement for the same amount of money, by the practical doubling of the funds available under the provisions of the State Aid Act. Consequently, little assistance of the character heretofore rendered has been asked for by the counties, although several of the towns of the State have applied for, and received, such assistance from this office.

Numerous tests of paving materials, cement, and other substances have been made in the testing laboratory of the Highway Division during the years 1906 and 1907. Most of these have been made for the city of Baltimore which has frequently referred to the Survey the materials to be used in various public works. The submission of samples to certain prescribed tests shows their relative values, and the municipalities in this way are protected against loss in the use of bad materials. The laboratory is equipped with special apparatus for testing vitrified brick, "belgian" blocks, crushed stone, cement, and other materials. Over 300 tests were made during the past biennial period.

The survey of State properties has been continued at the request of the Governor from time to time when the men were not required for other purposes. The survey of the Springfield Asylum grounds at Sykesville, the largest property owned by the State, has now been entirely completed and plotted. The surveys of the State properties at Annapolis have also been finished, while work has been started on the State Insane Asylum grounds at Spring Grove. It is the intention of the Highway

Division to continue the survey of the remaining State properties as rapidly as possible. When finished, an atlas of these properties will be compiled and published, since it is desirable that the State authorities should have in readily available form the facts concerning the exact location of the boundaries of these properties, as well as their topographic features.

The work under the State Aid Road Law, commonly known as the "Shoemaker Law," has been actively continued, and a wider appreciation of its provisions has become apparent as additional roads have been built. Already 75 miles have been completed under this law. Surveys and specifications have been made for 150 miles, and applications have already been received at the office of the Highway Division for 274 miles. Much greater results might have been secured during the three years that the law has been in operation if the people of the State had more fully understood the intent of the Act and the methods which the State Commission is pursuing. This law, in its most essential particulars, is like the legislation which has proved so successful in Massachusetts, Connecticut, New York, and New Jersey.

There have been the delays incident to the organization of a new movement as well as those due to a number of secondary causes. The most notable of these has been the scarcity of labor for all purposes in the State in the past two or three years, the unfortunate weather that has prevailed during the summers of 1906 and 1907, when the rainfall was excessive, and the difficulties in quickly securing the needed materials for the roads under construction.

The passage in 1906 of an Act, commonly known as the "Hill Law," providing for the building of a State road, independently of the counties, between Baltimore and Washington, inaugurated a new movement in State highway construction. It was felt by those advocating this measure that some of the main thoroughfares of the State should be built by the State alone, while the counties could still continue to build the less important roads under the existing State Aid Highway law.

For the building of the Baltimore-Washington road (State road No. 1) $30,000 was made available for each of the fiscal years 1906, 1907, and

1908. Provision was also made for the use of such convicts from the House of Correction as could be advantageously employed. Work began under this Act in 1906 and has been pushed as fast as practicable. Already about 12 out of the 30 miles of road have been completed. The present appropriation is about exhausted, and if the work is to be completed, another appropriation by the General Assembly of 1908 will be necessary. If the present grade-crossings of the steam railroads are to be avoided, it will probably require not less than $150,000 to complete the work. It seemed desirable, because of the large traffic which would necessarily be developed on this highway, to provide for the reduction of the grades, the building of a relatively wide macadam surface on the approaches to Baltimore and Washington, the abandonment, where possible, of grade crossings, and the straightening of the road in many places.

RECOMMENDATIONS.

The Commission feels, in view of the widely awakened interest in road matters and the present discussion of proposed legislation for the early improvement of the roads of the State, that it should report the conclusions it has reached as a result of its experiences to date in State road construction. These are as follows:

First. That the early improvement, according to modern methods, of an efficient system of main roads and feeders covering the whole State is desirable from every standpoint.

Second. That it is not only proper, but good business judgment on the part of the State to provide that the main arteries of this system should be improved and maintained by the State Commission at the expense of the State.

Third. That the improvement of the remainder of the system should be at the joint expense of the State and the counties.

Fourth. That the minor roads should be built and maintained by the counties and localities themselves.

Fifth. That present conditions have shown the importance of many of the turnpikes as sections of the general system. While undoubtedly the operation of these highways has contributed in the past to the

development of the State, conditions are rapidly approaching the point where their further existence as toll roads is entirely undesirable. Any legislation looking to the abolishment of the turnpikes as toll-roads should recognize the private rights and property values in the turnpikes themselves, and in all cases of assumption by the State or counties of the turnpikes, fair compensation should be made to private interests for the property taken from them.

Sixth. That any legislation providing for the taking by the State of the turnpikes should allow great discretion to the State Commission to prevent the acquisition of unnecessary property or turnpikes unsuited to the development of a system of market roads. Such legislation should be broad enough to allow the Commission to acquire for the State, for improvement and maintenance, either turnpikes or main roads, as the case might require.

GENERAL HIGHWAY INVESTIGATIONS, ASSISTANCE TO COUNTIES AND TOWNS.

TESTS OF MATERIALS AND SURVEYS OF STATE PROPERTIES.
(Acts of 1898, Chapter 434.)

GENERAL HIGHWAY INVESTIGATIONS, REPORTS, ETC.

The investigations of the Survey, concerning the public roads of the State, though perhaps completed in a general way, should be considered unending if the records as to details are to be kept up to date, and the effort has been made during the past two years to keep abreast of the demands. As fast as new facts have been discovered, new deposits of materials needed in connection with road work, or new methods of road betterment suggested, this office has promptly and thoroughly investigated the new conditions and methods, and tested the new materials.

The destructive effect of fast-running automobiles, especially on the better class of macadam roads, has begun to be appreciated in this State. There is no doubt but that these machines, owing to the construction of their wheels, to their self-propulsion, and to the speed at which they are frequently driven, have brought about new conditions and demands for

the Road Engineer to meet. These conditions may be briefly stated to include (1) objectionable clouds of dust in dry weather; (2) rapid removal of the fine "binder" from the surface of the macadam, resulting in the loosening of this surface and its final destruction, leading ultimately to the destruction of the road; and (3) the effect on, and disturbance to, the other users of a public highway by a swiftly travelling automobile, especially when driven at an excessive speed.

This last question may seem one more appropriate for an officer, or a maker of the law than for an engineer, but whenever the law is admittedly inadequate in construction or operation to furnish a satisfactory solution of the problem, the demand then reaches the engineer who is expected to supply the lacking protection to the general public by such forms or methods of construction as may be efficient. In a later part of this report the further discussion of this matter will be taken up.

For some time past, the need of an up-to-date map of the State, showing the public roads, has been apparent. This need was emphasized by the duties imposed on this Commission under the State Aid to Highways Law of 1904. Under this Act, the judgment of this Commission, as to whether the general public welfare of the State would be furthered by the extension of the aid of the State treasury toward the improvement of a particular road, was demanded and it was difficult, in some cases, to arrive at a fair conclusion in the absence of a complete road map of the State. Many demands from other interests and from the general public seemed also to emphasize the desirability of such a map. The completion, by this Commission, in co-operation with the United States Geological Survey, of a large number of the county surveys and maps, furnishing most of the necessary data, a road map of the State has accordingly been published on a scale of three miles to the inch, and it is believed it will be generally appreciated. The map is compiled from the latest available data, and, with the exception of a small area in the north central portion of the State, is from recent surveys. The field work on the portion referred to being still in progress, this edition of the map was compiled from the best and latest available data. It was felt wiser to issue the

FIG. 1.—OLD CULVERT ON RIVER ROAD BETWEEN CUMBERLAND AND CRESAPTOWN, ALLEGANY COUNTY.

FIG. 2.—IMPROVED CULVERT ON RIVER ROAD BETWEEN CUMBERLAND AND CRESAPTOWN, ALLEGANY COUNTY. BUILT BY COUNTY ROADS ENGINEER.

map in this form at the present time and to correct this portion at a later date, after these surveys had been completed, than to delay the issue entirely until the surveys should have been finished.

In addition to showing on the map the existing public roads and turnpikes, and, also, by a suitable designation, those stretches of road already improved under the State Aid Law, the attempt has been made to show a system of modern roads for the State, and how such a system, comprising less than 12 per cent of the total mileage of the public roads would serve by far the greater part of the public needs. It is by means of just such systems of improved roads that the States of New Jersey, Connecticut, and Massachusetts have met the demands of their citizens and acquired their just reputations as States with good roads. It is also along such lines that the more progressive southern and western States have more recently taken up their work of road improvement.

In suggesting any such system, it is fully realized that the judgment, as to the routes to be selected, and many of the other details, of one man or one commission, is neither infallible nor even beyond criticism, but with the system shown as a starting point and with the co-operation of others interested, and even better informed, the highest ultimate success in its design is assured.

The advent of the automobile on the public highways, as already referred to, has created new conditions and new demands. Heretofore, the Road Engineer had simply to design a surface fit to protect the road foundation from the destructive effects of weather, of the shod feet of draught animals, and of hard-tired wheels running at a moderate rate of speed. With the modern, high-powered, fast-speeding, rubber-tired automobile recognized as an inevitable condition to be henceforth considered and provided for, some means of preventing the disagreeable and destructive effects of its frequent use on macadam surfaces must be evolved. Where the machines are few, compared to the animal-drawn traffic, it may be said that their destructive effect is so slight as to be scarcely worth any additional expense in providing against. The other traffic will provide a sufficiency of binder, despite the sweeping effect of

the machine, and also keep the stone properly packed down. The machine, however, in even moderately dry weather raises such clouds of dust that some protection against such a nuisance is demanded. Temporary improvement may be secured by sprinkling with ordinary water. More lasting effects are obtainable with the use of sea-water (or its refinement, a solution of sodium chloride), but this is open to serious objections from a sanitary standpoint. Very satisfactory results are secured by the use of oils in various ways, generally in emulsions, some of which are patented, while others are not. The use of some of the heavy oils, rich in asphalt, from western Kentucky, Indiana, and California has been very successful, but the necessity of the asphalt base has been most strongly emphasized by the complete failures which have occurred in the use of oils, such as those of Pennsylvania, with the paraffine base. All use of emulsions, to be effective, must be continuous during dry seasons, and the applications must be made as frequently as conditions demand. Some of them undoubtedly have a slight effect, not only in keeping down the dust, but also in preserving the road against destruction by storms and frequent automobile travel. Their main value is, however, as dust-layers.

When the frequency and speed of the machines become so great as to effect the macadam itself, further efforts to protect it must be made. The destruction caused by these vehicles consists first of the removal of the "binder" or small particles of stone from the interstices of the surface layer of stone, then in the loosening of the bond in this layer, and finally in the dislodging and removal of the successive layers of the macadam into windrows alongside of the tracks of travel. Any road composed of broken stone and even asphalt pavements themselves seem, if left to themselves, to be unable to withstand indefinitely the suction apparently exerted by the pneumatic tires of the automobile, shod in various ways, and the sucking and sweeping effect of the car, driven at a high speed, by the grip of the wheels on the road surface.

To enable a binder to hold its proper place under the action of frequent automobile travel, and thus to postpone, if not to prevent, the ultimate destruction of the macadam, various means have been tried. As before stated, emulsions of proper oils have some beneficial effect, but,

to meet severe conditions, their use must be so frequent as to suggest the advisability of using the base itself instead of any dilution of it. The use of properly refined oils with an asphaltum base has given fairly satisfactory results in many places. It must be admitted, however, that this process, while promising, has not as yet been developed sufficiently to warrant the unreserved approval of it under all conditions.

Probably the most successful attempts to prevent the destruction of macadam under frequent automobile traffic have been made with the use of refined coal-tar, nothwithstanding the natural advantages that asphaltum may possess over this material. The refining of coal-tar for this purpose, and the methods of using it have been intelligently considered and fairly well worked out.. Where the results of these considerations have been carefully followed the success has been marked, although at times, there have been apparent failures due to defects in the macadam treated. Numerous other failures in the use of coal-tar have resulted from the employment of improperly prepared tar, its unskillful or unintelligent application, or its use under circumstances and conditions so evidently unfavorable that they should have prevented even a trial.

The best results and the maintenance of a tarred road can only be secured by repeated applications of the tar, but the interval between applications grows successively longer as the penetration increases. While the tar retains its life, the road successfully resists the heaviest automobile traffic, but the moment this life disappears or the layer of tarred material is worn through, the road is again in danger. Tarred macadam also nullifies the washing effects of storms and diminishes the destructive action of frosts, and practically prevents dust existing on the road unless animals are admitted to it, or mud is brought on in wet weather from adjacent fields or intersecting roads. Properly built and tarred macadam may yet prove a solution for the question of securing road and street surfaces to meet certain conditions of traffic without involving the enormously higher costs of block or patented pavements.

The fact that automobiles do injure the roads and the observation that this damage is proportional to the rate of speed inevitably presents the question of how to protect, not only the users of the road, but the road

itself from excessive speeds. Although, as before stated, this office feels that its entrance into the purely legal phases of the question or into the matter at all, until the legal authorities admit their failure to handle it, would be merely an unwarranted intrusion; still when the public admits the inefficacy of the law and the failure of authorities entrusted with its enforcement to prevent excessive speed, and applies to this office for relief, the consideration of means of relief becomes imperative. A solution that has been most successful in its prevention of excessive speed has been the construction at fairly frequent intervals in the macadam of artificial ridges (or trenches) extending across the axis of the road and of a height (or depth) sufficient to absolutely deter the most rabid "scorcher" from more than one attempt to maintain an excessive speed over a road so constructed.

The presence of such "breakers," as they are popularly called, is, however, slightly objectionable to ordinary travel and is further likely, by possibly obstructing the proper drainage of the road or by encouraging the formation of pools of water on the macadam, to shorten the life of the latter, and thereby increase the cost of its maintenance. It would seem far better, therefore, to rely on proper public opinion, laws, and legal authorities, to control and protect both public and roads against the excessive speeds, by for example, regulating the gearing of high-powered machines so that excessive speeds are impossible, rather than to call for such control and protection by devices of construction which in themselves are departures from the best possible methods of road building.

GENERAL ASSISTANCE TO COUNTIES AND TOWNS.

Since the "Shoemaker Law" has been operative, counties that previously had attempted, with the technical assistance of this office, to make certain permanent improvements each year with such funds as they could annually set aside for this purpose, now devote these same funds to work under this law. The practical effect is to double the amounts available for permanent improvements, and, at the same time, to render the technical assistance free. The other calls for technical assistance are, however, correspondingly reduced.

Calvert County secured permission from the General Assembly of 1906 to issue bonds for the purpose of rebuilding the bridge to the mainland at Solomon's Island. The assistance of this office was requested and furnished under the State Aid Law. The old bridge was a pile structure 500 feet long. Extensive repairs were necessary every few years because of the destruction caused by the teredo worms. After careful investigation, including the consideration of various forms of construction, such as concrete piers, spans of various numbers and lengths, protected piles, etc., this office recommended a bridge of 26 spans, each 20 feet long, with concrete piers and abutments, and with sufficient wing walls to protect the fills behind the latter. The Survey offered the aid of the State to the county to the extent of one-half the proper cost of such construction. The county authorities, however, appeared to underestimate the value of the provisions in the State's plans and specifications for substantial work and decided that the expense to the county of carrying out the State's plans ($3800 to $4000) could be reduced by the county attempting the work alone. Accordingly, the county modified, to meet the ideas of their authorities, the plans of the State (by omitting some of the foundations, replacing steel girders with chestnut, and white oak plank with red oak, etc.) and built the bridge in the winter and spring of 1906-07. In October, 1907, an inspection revealed the fact that one of the piers had already sunk on one end and the lumber was showing signs of decay. It is understood that the first cost to the county was actually about $5000, not counting subsequent repairs.

In Prince George's County, the road authorities applied for State aid on a portion of Central Avenue near the District Line. In response, plans and specifications were prepared by the State and bids on them were asked by the county. A reasonable bid was received, and the county authorities were advised that their execution of the contract would be approved by the State. When the signed contract was returned to this office, however, it was found that in executing the same, a change had been made in the specifications so as to permit the use of gravel from a certain bank instead, as originally provided, gravel with certain char-

acteristics. The county authorities were at once notified that the State's approval of this action was refused on the grounds that not only was such action unfair to other bidders, but also that, under the modified specifications, proper protection against the use of inferior material could not be guaranteed the county, notwithstanding the apparent good quality of the gravel exposed in the deposits named. The county authorities thereupon decided to carry on the work independently of the State, and, at their request, this office has furnished them with the plans, stakes, etc., necessary for them to do so.

In 1906, work was begun on the Braddock Heights Road in Frederick County under an approved contract for about one and one-half miles. After completing about one-half mile, according to the contract, from the turnpike southerly to the turn into the new road, the contractors and the county decided to end the original contract at this point and to do any further work under modified specifications permitting inferior material and methods which were unacceptable to the State. The assistance of the State was therefore cut off at the point mentioned, except that the plans furnished by the State were used in the additional work on this road.

Among the roads for which Baltimore County requested State aid was Belvedere Avenue between Park Heights Avenue and the Reisterstown Turnpike. Owing to the large amount of purely local travel over this particular piece of road, the county was advised that while the interests of the State as a whole seemed, perhaps, to justify this Commission in the approval of the application of the county for State aid on this section of road and the contribution by the State of one-half the cost of not only the standard 14-foot macadam, but also one-half the cost of proper grading and draining of the road to a maximum width of 60 feet, they did not warrant the rendering of assistance to a larger amount. It was then recommended that the county itself, in order to reduce to the minimum what would otherwise be an excessive annual maintenance expense, increase the width of the macadam to a maximum of 24 feet. It

FIG. 1.—CHESAPEAKE AVENUE, BALTIMORE COUNTY. BEFORE IMPROVEMENT.

FIG. 2.—CHESAPEAKE AVENUE, BALTIMORE COUNTY. AFTER IMPROVEMENT BY COUNTY ROADS ENGINEER.

was estimated that the proper cost of carrying out the plans thus recommended would be about $8400, and that the State was justified in contributing $2900 of this amount. This arrangement was unsatisfactory to the county authorities, who asked that the cost be shared equally by the State and county. This Commission has not felt, after careful consideration of the principles underlying the State Aid Law, the financial condition of the State, the interests of the general public, and the particular local interests concerned with this improvement, that it would be justified in responding to the demands of the county authorities. The latter have, therefore, arranged for some work on this road at their own expense, and this office, at the request of the County Roads Engineer, has gladly furnished the county with the plans and information necessary for their work.

A section of Boyce Avenue about 3500 feet long, beginning at the westerly end of the same has been improved under the State Aid Law. In the absence of satisfactory bids for this work, the regular county forces have carried it on. Notwithstanding most unfavorable conditions of all kinds, and in spite of the quite prevalent opinion regarding the inefficiency of labor employed in county work, the cost has been less than 80 per cent of the lowest figure bid. As the extension of this improvement to Charles Street seemed likely in the near future, and as some grading on Charles Street near the junction was in progress at this time, this office, at the request of the County Roads Engineer, submitted a plan for the grading at this time of the easterly end of Boyce Avenue near the Charles Street intersection so that unnecessary expense might be avoided in the future. So far, however, the county authorities have not followed the plan suggested.

Several of the more progressive towns of the State have been advised by this office in engineering matters, principally, however, on points of street improvement. Among the towns thus receiving the assistance of this office are Frederick (with tests of materials); Baltimore City

(tests); Annapolis (tests, advice and supervision of work); Easton (advice); Salisbury (advice).

Other State commissions have been supplied with such advice and assistance as this office has been able to render. The Commission for the improvement of the State House Grounds was supplied with advice, surveys, plans, supervision of work, etc.; the Tuberculosis Hospital Commission is now being furnished assistance by this office, in direct management and supervision of the construction of a road through its property; and the management of the House of Correction is being furnished advice and assistance in its road work.

TESTS OF MATERIALS.

The work of the testing laboratory has been carried on as occasion demanded. No material is approved for use on State-aided roads or recommended for use by the counties until full tests have been made, and its value for road or other purposes fully determined. The services of the laboratory are in frequent demand by the various county and municipal authorities, especially those of Baltimore City and the larger towns of the State.

Tests of materials for various parties in the years of 1906 and 1907 have been made as shown in the following table:

Baltimore City:	Brick.	Stone.	Concrete.	Cement.	Total.
Annex Improvement Commission..	22	5		5	
City Engineer, Baltimore.........	126	3			
Park Board				2	
Sewerage Commission	14				177
Baltimore County Roads Engineer..	13	11		2	26
Caroline County				5	5
Carroll County		1			1
Frederick County		1			1
Howard County		1			1
Washington County		1			1
State Road, No. 1..................		1		13	14
Miscellaneous	25	16	19	28	88
Total number of tests..........	200	40	19	55	314

SURVEYS OF STATE PROPERTIES.

The work of surveying and mapping the various properties owned by the State, which was begun in 1904, has been carried on as conditions have permitted. The demands on the force at the disposal of this office, since the operation of the State Aid Law and the Act providing for the improvement of the Baltimore-Washington Road, have been so nearly up to the limit of work of this force that progress on the surveys and maps referred to has been slow. Some have been completed, but it has been impossible to take up many others quite as important. The work is much needed, and, if finished, would be exceedingly valuable to the State, but if it is to be completed in the near future, some further definite appropriations for the use of this office in this work should be made by the General Assembly.

STATE AID TO COUNTIES.

(Acts of 1904, Chapter 225.)

The Highway Division has been continuously occupied during the past two years with its duties under the so-called "Shoemaker Law." As familiarity with the provisions of the Act itself and with the results on the roads has increased, evidences of general approval and satisfaction with both have multiplied. At first a complete understanding of the intent and aims of the Act was infrequent. This, combined with the changed methods of work, the considerably higher first cost of securing the results demanded, and the value of the unusual results themselves, not only failed to inspire enthusiasm for the law, but in many instances aroused active opposition, especially from county officials. With the lapse of time it has been possible to demonstrate the value of a departure from the former loose and unchecked methods of awarding contracts for road work to more or less incompetent parties, and with little or no guarantee that work and materials paid for were actually furnished; furthermore, that the expenditure of a comparatively large sum on a section of road did not necessarily mean that such was a waste, but might, on the other hand, actually prove the more economical course

in the long run; that not only were results possible in road work hitherto unknown of by the residents of a locality; and that such high grade results were worth some extra expense to the public by reason of their fine appearance, comfort, and utility, not to mention the reduced expenses for repairs, maintenance, etc. This demonstration has been followed in most instances by a public endorsement of the work. In every locality where the completion of the improvement of a section of road has been secured under the State Aid Law, a demand for its extension has followed. In some instances, the advantages secured by the fortunate locality, through which the improvement runs, have been so apparent as to cause concerted action in adjacent neighborhoods for securing on their roads some of the same kind of work.

Some opposition to the work has come from parties or localities which have been unable thus far to secure the improvement of their particular roads. The selection of the roads to be improved is very properly left by the Act in the hands of the county road authorities, and consequently any criticism on this ground should be presented to the latter and not directed against the Act. Some other opposition has arisen on account of the cost of the work done, though this has mostly been either from lack of information or from misinformation regarding the details. It is perfectly true that the work done under the State Aid Law has on the average required a much larger expense per mile of road than has been customary in the case of county work, but it is not true that the actual cost has averaged more than the average cost of similar work elsewhere, nor in many cases more than the cost of equal quantities of work done by the counties themselves with inferior results. It is unfortunately true, however, that excessive prices have frequently been demanded by those bidding on work offered under the law. This has been chiefly due to the extraordinary demands then existing for both labor and materials; partly to lack of competition; and partly to ignorance and misapprehensions on the part of prospective bidders. In some cases it has been felt best to agree to high prices rather than prevent the improvement. In others, the counties have been induced to purchase the needed materials, and to employ the necessary labor under the supervision of

FIG. 1.—SECTION OF GWYNN OAK AVE., BALTIMORE COUNTY.
BEFORE IMPROVEMENT.

FIG. 2.—SECTION OF GWYNN OAK AVE., BALTIMORE COUNTY.
AFTER IMPROVEMENT UNDER STATE AID.

the State, with the result that in every case, where fair management of the work on the part of the county was secured, the cost was well within the estimates. As one of the aims of any State Aid Law is to instruct the regular county officials, as well as to aid financially in road improvement, it seems that the performance of work by the county road gangs, in cases where excessive prices are demanded by contractors, would not only serve to prevent waste of public moneys but also benefit the forces themselves by the experience derived from working under the supervision of the State.

The results on the road, attained under the supervision of the State, compare favorably with the results of similar efforts in other States, and are no finer than experience has proved absolutely necessary if economy, permanency, and the ultimate establishment of an efficient system of improved roads for a State are desired. This is not a matter of guess-work or theory. For generations the county officials have spent annually on the roads of the State sums running in 1904 to nearly three-quarters of a million dollars. Yet there has been and is daily complaint about the condition of the public roads in general. Another State has for ten years spent, along lines and methods identical with those of the recent work under the "Shoemaker Law," less than $500,000 annually for that period and secured results which have advertised that State all over the country as a State where all the roads are fine. The old methods and systems have had a sufficient trial to prove them unbusiness-like, extravagant, and unsatisfactory in results. And the only favorable results anywhere in evidence to-day are those secured in a comparatively short time under the new methods and laws. Naturally, perhaps, some antagonism to the new methods, and to the necessary interference with their formerly unlimited and unchecked authority, has appeared to exist in the attitude of some county officials. In one or two cases this opposition has been carried to extremes. It is felt, however, that such opposition cannot last and that the public interests will soon outweigh any personal considerations.

One question worthy of serious consideration has arisen in connection with the work under the State Aid Law, and has quite likely had some

effect in decreasing the results under it. The Act requires the improvement to be completed and paid for in full by the county before any money is paid to the county by the State. After careful study of this matter, it is not yet clear how, with due regard for all existing conditions and proper protection of the State itself, any other solution of the problem of securing the necessary cash funds for this work can be offered, than by the raising of the cash by the counties themselves. It may be done either by an increase in the annual tax rate or by a bond issue.

Already one or two of the counties have met the question squarely and in a progressive manner and the results seem to be approved. Some of the richer counties have annually set aside a fund from the tax levies for permanent improvements. Others have borrowed the cash necessary for the purpose, and set aside annually enough from the tax levies to meet the interest and sinking fund requirements of the loan. This latter method seems to have the advantage of securing greater and quicker results on the roads with less annual burden to the taxpayers than any other yet practiced.

Once the general improvement of the main roads of a State is completed, experience has proved it entirely possible to maintain them indefinitely in this condition, by intelligent and honest work, within a reasonable annual tax levy. And it would seem that with a contribution from the State treasury of one-half the first cost, to say nothing of private contributions, the counties of Maryland ought to be able to raise the balance with ease.

One of the most valuable features of the present State Aid Law is educational. Whatever hazy ideas may have been held by any individual or the public regarding the characteristics of a modern "good road," or however wanting these ideas may have been, the construction under this law of short or long sections of modern road throughout the State has had a powerful influence toward general road improvement. Until recently only a comparatively small proportion of the residents of the State were familiar with modern highway work and scarcely any were familiar with its economies, and an engineer was an unnecessary luxury in roadwork, if not a positive evil to be avoided. This state of affairs has

materially changed in the past few years. Another county (Somerset) has joined with Allegany, Baltimore, Caroline, and Prince George's in employing a roads engineer. As above stated, bonds of short period for road improvement, formerly unheard of or fearfully dreaded, have been issued by some counties and others are agitating the question.

The effect of examples of proper road construction and maintenance is already visible in the work done on the other county roads in the localities near or in which a section of State-aided road has been built.

When the next step, which is already under consideration, is taken, and the toll-gates are abolished, and main highways are built and maintained at the expense of the State, it will be a direct result of the educational influences of Chapter 225, Acts of 1904.

STATE ROAD NO. 1.

(Acts of 1906, Chapter 312.)

The precedent for the State's assuming directly the expense and responsibility of a through road between important points was established in the so-called "Hill Law," which provided for the improvement of the old Baltimore-Washington Turnpike, sometime ago abandoned as a toll-road. The condition of the road had been steadily growing worse, and the Act appropriated the sum of $30,000 annually for the years 1906, 1907, and 1908 toward its improvement, with the provision that as the State took hold of a section, it thereupon passed from the county or town into the direct control of the State authorities.

Realizing that the total appropriation carried by the Act would be insufficient to complete the improvement of the whole of the 30 miles of the road, especially in view of the desirability of abolishing, if possible, all seven of the present dangerous steam-railway grade-crossings, this Commission felt that the public interest would be best served by the expenditure of the appropriations on those sections then in the worst condition, and on which no questions of change in permanent location had arisen or seemed likely to come up.

It was clear from the language of the Act that substantial work was called for and an attempt has been made to secure modern and thorough

work at the least possible cost compatible with its importance. It is understood that the results on the road are satisfactory to those familiar with them. If the work of improving this road is to be completed between the limits of Baltimore City and the District of Columbia, the further appropriation of not less than $150,000 will be necessary.

The bill to provide for this work was introduced in the House January 23, 1906, was passed by that body March 27, by the Senate on March 31, and received the signature of the Governor April 2. It is as follows:

LAWS OF MARYLAND

ACTS OF 1906

Chapter 316

AN ACT TO PROVIDE FOR THE CONSTRUCTION OF A STATE ROAD OR HIGHWAY THROUGH PRINCE GEORGE'S, HOWARD, AND BALTIMORE COUNTIES, FROM WASHINGTON, D. C., TO BALTIMORE, MARYLAND.

Whereas, A public sentiment exists in favor of the construction of permanent public highways in and through the State of Maryland, with a view to have the people of the State to emulate the example of other States in this respect, and

Whereas, The most available points to build such a highway as an object lesson is between Washington and Baltimore; and

Whereas, Initial proceedings in respect of such work have been instituted by the enactment of Chapter 51 of the Acts of 1896, and of Chapter 434 of the Acts of 1898, and 225 of the Acts of 1904, creating and defining the duties and powers of the "State Geological and Economic Survey Commission"; therefore

SECTION 1. *Be it enacted,* That a public highway, to be known as State road No. 1, be and the same shall be constructed between the cities of Washington and Baltimore, the course of which, as near as practicable, shall be along the route of the old Baltimore and Washington road, the bed of which, so far as the same is vested in the State or the several counties through which it passes, is hereby dedicated by way of easement or fee simple, as the case may be, to the public use.

SEC. 2. The building, grading, and construction of said road shall be under the direction and control of the State geological and economic survey commission, but it shall in no place be less than thirty feet nor more than sixty feet in width; and wherever the said road as hereinbefore laid down by said commission shall pass through any incorporated towns, unless the said towns shall grant an easement therefor over a street or streets to said commission (as representatives of the State), the said commission is hereby authorized and directed to divert the same so that it may pass around such town as may refuse to grant such an easement as aforesaid.

SEC. 3. Whenever it shall become necessary from any cause to acquire any lands for the purpose of constructing said road which cannot be acquired by purchase or grant, the said commission is hereby clothed with power to condemn, under the right of eminent domain, as now conferred on railroad or railway companies by Article 23 of the Code of Public General Laws, title "Corporations," or as may be conferred on such corporations by any amendment to said Article 23; this right of condemnation to apply to gravel pits or quarries as well as to land, and whenever it shall be necessary to cross any streams the bridges over the same shall be constructed of permanent materials and in a modern manner.

SEC. 4. Whenever any railroad or railway company hereafter constructed shall cross said road it shall be required to keep its own roadbed and the bed of the said highway in proper repair or else to have constructed an overhead or undergrade crossing subject to the approval of the said commission or in conformity to the provisions of Article 23

of the Code of General Public Laws as to crossings of railroad companies in regard to flagmen and electric bells; and the tracks of such railroads or railways shall be so constructed as to give absolutely safe and easy approach to and crossing thereof; and in case of failure so to construct, the said commission shall construct the same, and upon certification of such construction and the cost thereof, after due notification to such company to construct and its failure so to do the cost thereof shall *ex parte* be rendered a judgment against such company by any justice of the peace in such counties before whom such proceedings shall have been instituted.

SEC. 5. For the purpose of building and constructing and maintaining said road or highway, the said commission is hereby authorized and directed to make requisition on the directors of the Maryland House of Correction for as many inmates thereof as may be necessary for the said purpose of building and constructing such highway, and the said directors are hereby directed to furnish the same with such guards or keepers as can be spared from their duties at said House of Correction, and any additional guards or keepers necessary to the safe keeping of said inmates shall be furnished and appointed by said commission. The said commission shall, in conjunction with the aforesaid board of directors of the House of Correction, provide for the maintenance and safekeeping of said inmates of the House of Correction.

SEC. 6. For the purpose of carrying out the provisions of this Act the sum of thirty thousand dollars is hereby appropriated out of any moneys in the treasury not otherwise appropriated, to be used during the current year of 1906, and are to be paid by the warrant of the Comptroller on the Treasurer upon certificate of the said commission, as directed by them; and the further sums of thirty thousand dollars each annually for the fiscal years of 1907 and 1908 be and the same is hereby appropriated for this purpose.

SEC. 7. And the said commission is hereby authorized to purchase such machinery, teams, implements, and materials, and employ such assistants as may be necessary to the proper construction of said road or highway out of the sums appropriated by Section 6 of this Act, and use the same in the construction of said road or highway, and after its completion the same shall be and remain as the property of the State of Maryland.

SEC. 8. *And be it enacted,* That this Act shall take effect from the date of its passage.

Approved April 2, 1906.

GENERAL AND SPECIAL CONSIDERATIONS.

MAP AND SUGGESTED SYSTEM OF MAIN ROADS.

Not by any means the least of the work of this department during the past year has been that of getting out a new road map of the State. Up to the issue of this map, not only was there no reasonably accurate road map of the entire State to be found, but nothing covering the whole State had ever been issued giving such special information. The new map, in addition to a great deal of other information, shows all the public roads of the State. It is based upon the present topographical survey, now nearing completion, conducted jointly by the United States Geological Survey and this Commission. The Survey has not yet covered certain portions of the State, especially those represented in the northern central portion of the present map, which is compiled from the best information

obtainable and can be corrected as the later data are secured from the surveys now in progress.

The map shows a suggested system of improved roads built according to modern ideas, and clearly shows the benefit which such a system would be to the entire State. Such a system is undoubtedly the ultimate intention of the law providing for State Aid. The details of the system suggested are by no means final or incapable of improvement, and it is hoped that a careful consideration of the suggested system will result in its modification until it becomes the best possible that can be secured. There are also shown in connection with this road system, the pieces of road already completed under the "Shoemaker Law." It will be noted that here and there a section of road is shown as completed, which is not a part of the suggested system. This fact may come from incorrect judgment in the system suggested, or it may be due to the liberal attitude adopted by this Commission up to the present time. Many applications have come in for aid on roads when it was not clearly apparent that the road named would form part of any such system as is here proposed. Still, in view of the fact that the law embraced in its aims not only a system of roads but also the equally great object—namely, the education, by demonstration, of the masses of the people of the State of the characteristics and value of roads constructed according to modern ideas—the Commission has felt that as long as no county would be deprived of any State aid on roads clearly forming a part of a State system, they should consider all applications. Since the roads not so evidently a portion of the system are still important enough to warrant considerable expense for their improvement on the part of the county, the Commission has deemed it wise to respond, at least during the first few years of the work, to the requests for aid on these accessory roads in order to fulfill the educational intent of the law.

LIMIT TO STATE AID.

In order to avoid falling into the error of embarrassing the county authorities, or of spending extravagantly the money of the State for purely local improvement, the Commission has been obliged to adopt a

maximum limit to the aid which the State will give to the improvement of any particular road. The interest of the State at large in any road is no more than the demands of the general public on that road, and in the term "general public" is included not merely the interests of the abutters and the purely local traffic, but the traffic that may come from a considerable distance, and possibly even from outside the State. The Commission has therefore adopted a standard width for the macadam surfacing which will answer all the demands of the general public. Any demand for a macadam wider than the State standard is due to the requirements of the local traffic, and the expense of meeting it should be paid by the locality.

The neglect to establish such a maximum, representing the interests of the State at large in the improvement of a road, would result in the expenditure of the money of the State and county for local developments, and in those sections best able to raise the funds for road improvement. The whole idea of State aid is quite the contrary to such development of favored localities, and it is to be regretted that, even under the rulings of this Commission, more work has not been done by some of the counties farther away from the centers, where the aid is more needed, and the results of the improvement would be more effective.

MISUNDERSTANDING OF OBJECT AND OPERATIONS OF THE STATE AID LAW.

A great deal of misinformation concerning the aims, operations, and results of the State Aid Law is extant. Some seem to think that the object of the law is to secure the macadamizing of each of the 16,000 miles of public road in the State at the joint expense of the State and county, and at the cost of from $5000 to $6000 per mile. It may be clearly stated that such is *not* the intention of the law or of any other State aid law that has ever been passed. In some cases, other States have expressed in their laws that it was the intention of such laws to provide for a system of good roads through the State in question. Such was evidently the intention of this State—that a system of main roads should be improved by the State and counties acting together. This system would probably keep pace with the growth of the State, and would, of

course, be capable of extension as the resources of the State increased. The effect of such a system of good main roads would be double. The roads themselves would exist for the convenience of their use, and their very existence could but improve, by the force of their example, the tributary roads built and maintained by the local authorities.

One frequently hears that Massachusetts is a State of good roads. As a matter of fact, out of perhaps some 18,000 miles of public county roads in that State, less than 1400 miles have been macadamized, the average cost being approximately $7000 per mile. However, the selection of the roads to be improved has been made with such good judgment that a system of fine roads meeting the demands of the average traveller, has been secured, and the resulting impression of the visitor is that all the roads are fine. The same state of affairs exists in New Jersey, Connecticut, and many other places, and it is hoped by this office that it may soon begin to appear in Maryland.

The operations of the law are also not yet fully understood. The $200,000 set aside for the improvement of highways comes from the general revenues of the State. As this fact becomes more widely known, there will undoubtedly be a wider appreciation of the present Act and a better recognition of the State's interest in supervising the expenditure of this appropriation. Some citizens still believe that the State appropriation for this purpose is raised by direct taxation, and that a portion of the present State tax of 16 cents is levied to make up the amount expended under this law. Such is not the case.

We find that there are localities where it is still believed that contributions from abutting property owners must be made in order to secure State aid. Of course, inaction on the part of the County Commissioners could readily bring about this state of affairs, but the clause of the State Aid Law on this point contains nothing obligatory to the property owners.

DIFFICULTIES AND DELAYS MET WITH.

The actual methods of conducting the work on the road are generally the subject of considerable criticism, especially where they are in opera-

tion for the first time in a locality. As the results, however, become apparent, and as familiarity with the methods increase, the criticisms usually disappear.

One great source of complaint has been due to the length of time that the travel over the road being improved was inconvenienced by the progress of the improvement, and sometimes these complaints have been justified. The weather, of course, cannot be controlled, and it must be recognized that in the past two years, the amount of rainy weather and the amount of time in which the conditions were unsuitable for road work has been unusually large. In addition, it has been difficult in many cases to secure the prompt delivery of material. Considerable improvement in the conduct of the work is possible, however, and should be made. The county authorities should make their plans so far in advance that the work of any year can be started at the first possible moment in the spring, and they should insist on the completion of that work within a reasonable time.

It has frequently been the case in the past that the work was either started so late in the year, or allowed to drag so slowly, that it was unfinished when the winter season arrived. At times also, the unfinished portions were left in such condition that the road was a great deal worse than it was before the work was started. Such action should not be permitted. Undoubtedly, when bidders for work were few, the temptation to award several contracts to the same party, in order to strengthen the prospects of ultimately securing improvement, was strong, but it does not seem good policy to award any one party more contracts than can be efficiently carried out by him.

RELATIONS OF CONTRACTORS, COUNTIES, AND STATE.

Considerable complaint has reached this office from one county where two or three contracts have been awarded to the same party before any one of them was finished, and the contractors have simply torn up and kept in a bad condition three or four roads for the same length of time that it would have taken to have begun and finished each one consecutively. This does not seem fair to the users of the road. This office can

the general increase in care in the selection in materials used for road improvement. Where ten years ago the invariable custom was to use the local materials for an improvement regardless of their value for road surfacing, the only exception being perhaps the oyster shells, it is now quite common to find limestone or other of the better class of materials for road surfaces being brought in from a distance of as much as 100 miles, where the local materials available for this purpose have been proved unsatisfactory. The wisdom and financial benefits to the county from such selection of materials has been proved to be unquestionable.

Similar improvement in the methods and results obtained in the various localities from the influences of properly executed work is apparent in the replacement of wooden bridges with more permanent structures of pipe or concrete.

COUNTY ROAD ENGINEERS.

Subsequent to the establishment of the State bureau, certain of the counties have obtained authority from the General Assembly for the appointment of County Road Engineers who are intrusted with the administration of the roads in their respective counties. This has greatly facilitated the work of the State officers since the County Road Engineers so far appointed have been trained men understanding the necessity of properly constructed roads and the methods adapted to securing them. The spheres of the County and State engineers are distinct and their duties separate. The local men by the progressive administration of their offices, their knowledge of local needs and conditions and their enlightened expenditures of their road funds in repairs and permanent improvements have accomplished much good in their respective counties. The State officers, with their knowledge of the needs of the State as a whole, their better-equipped and more highly-trained forces, have been able to co-ordinate the work in different counties and to give valuable assistance to the local engineers. The State Engineers have endeavored to help the County Road Engineers by the making of surveys, preparation of plans and specifications and advice before and during con-

struction, and in this effort they have received the hearty coöperation of the County Road Engineers. The division of the road work among the State and County engineers has been of mutual advantage, and it is hoped that the system of County Road Engineers may ultimately extend so as to include all of the counties of the State. At present there are Road Engineers in Allegany, Baltimore, Caroline, and Somerset counties.

The Engineers of Allegany, Caroline, and Somerset counties have labored under difficulties arising from great demands and moderate resources, but by skillful planning and intelligent work they have, by the results they have been able to secure, materially influenced the general road-work of the county. Especially is this so in the case of Caroline County, where the previous lack of system has been supplanted by a business-like method of carrying on the ordinary work of road-maintenance so that the efficiency is increased, the cost reduced, and more money for permanent improvements made annually available from the same total road fund. The expenditure of the moneys for permanent improvements is then carefully made along the lines of good modern work, and the results on the roads themselves are already appreciably evident. In Allegany and Baltimore counties, especially in the latter where the yearly road fund is large, under the influence of the County Road Engineers, the old wasteful methods of attempting modern results are gradually disappearing. While there still remain some evidences of "veneering" in attempting to satisfy annually many voters, the folly of so doing is generally recognized and public opinion is beginning to support the county authorities in their attempts to attain substantial results as fast as their resources will permit by permanent construction as far as their funds in hand will go, and subsequent extensions in the same manner as soon as new funds may permit. Wooden bridges have been replaced with concrete, wooden boxes with iron or tile pipe, and several stretches of modern macadam have been built according to modern methods and with results comparing most favorably as regards appearances and even cost with the best work in the State.

Many other beneficial results to the counties employing efficient and skillful Road Engineers have been evident and in every case the results

of such action have proved the necessary expenditures good investments for the counties.

ABSTRACT FROM REPORT OF ROADS ENGINEER OF CAROLINE COUNTY.

This county, like the majority of the counties of the State of Maryland, prior to July 1, 1904, worked all roads under the usual system of supervisors, until, with approximately 600 miles of public roads, it had in one year 108 supervisors. Under this same extravagant system, one county on the Eastern Shore of Maryland with approximately 550 miles of roads, appointed 175 supervisors during the last year. The taxpayers of Caroline County, realizing what the methods and procedures of such a system meant, and the cost to themselves with no results, held several public meetings in th fall of 1903. At these it was decided to draft a Road law which would do away with the old system and its political features and provide for the appointment of a Roads Engineer. Such a bill was passed during the session of the Legislature of 1904,[1] which included, among its principal features, the appointment of a Roads Engineer by the Board of County Commissioners, who should hold his position until removed for cause, after formal charges of incompetency or wilful neglect of duty, sworn to by ten or more taxpayers, had been filed with the County Commissioners, and proven after a hearing.

This practically eliminates political features and makes the Roads Engineer free from any political pressure. The Law, furthermore, gives the Roads Engineer the power to appoint or remove at will all supervisors who act under his control and direction. He also has full charge of all labor, teams, wagons, machinery, and implements that may be owned or purchased by the County Commissioners. He examines and certifies to the correctness of all bills for work done or for materials furnished before the same are paid by the County Commissioners.

Under this law, Mr. W. D. Uhler was appointed Roads Engineer July 5, 1904. In entering upon the duties of the position, it was determined to eliminate politics in every way, and to conduct the affairs of the office on a strictly business basis.

[1] Laws of Maryland, 1904, chapter 644.

OLD BRIDGE ACROSS CHOPTANK RIVER, GREENSBORO-DENTON ROAD, CAROLINE COUNTY.

The first problems confronting the Engineer were the selection of satisfactory supervisors for each of the eight election districts, the adoption of a proper system of accounts and records, the preparation of a road map, and the development of methods of working to fit the local conditions.

The selection of road supervisors was made, after consultation with prominent taxpayers and the personal investigation of the recommendations received, and men chosen who seemed best fitted for the work. The first selections did not prove in every instance to meet expectations and the personnel has gradually changed through the weeding out of old, and the substitution of new men according to their ability to work and accomplish results.

The system of accounts in vogue before 1904 made it impossible for the Commissioners to tell what work had been done or what liabilities had been incurred, since the supervisors frequently failed to render bills until six months or a year after the work was supposed to be completed. It was practically impossible to check the bills which were simply charged to the General Road or Bridge accounts. Accordingly the Engineer devised a new system.

This calls for a daily post-card report from each supervisor, showing the date, names of men working, time made by each, number of horses, their owners and time made, amount of material used and work done. These cards are then filed and used by the Engineer on his next inspection trip to check the work done and the material used. This enables the formation of correct conclusion as to whether or not a supervisor is doing work economically. Cards are also used in checking bills when presented, which, under the law, must be passed by the Engineer before payment. The bills are then charged to the respective districts in which the work was done, all bills being subdivided so as to show how or for what the sums were expended, the principal items being labor, teams, carpenters, lumber, hardware, pipe, feed, machinery, etc.

To further facilitate the work, a circular letter was issued to the Rural Free Delivery carriers, asking their coöperation in reporting any dangerous or unsafe places in the county roads on their respective routes.

Special post-cards were furnished for the purpose with the Roads Engineer's name and address printed on same. This has been of infinite help in the work as Rural Free Delivery covers at least 75 to 80 per cent of the roads, which practically means a daily inspection of the main roads of the county.

The changes made in the method of working the roads have been marked. At first, attempts were made to secure the teams necessary for plowing and scraping from the nearby farmers. This proved quite unsatisfactory for many reasons. The time most favorable for road work is that best suited for general farm work. When teams were secured, they usually were furnished by different farmers, each sending one of the four to six pairs used on a plow or scraper. Each pair had its own kind of harness and a driver who took care that his team pulled no harder than the others. Even such supplies could not be obtained for more than a day or two of continuous work. Altogether this method proved not only unsatisfactory but very expensive. Experiments were then made with a steam-roller which could plow, scrape, and roll. Traction engines were also hired at prices varying from $7.00 to $10.00 per day. After taking into consideration the expense, work done, etc., this method of hiring equipment was abandoned. Experience with a few mules owned by the county soon showed that the best method was for the county to own its own mules (buying the best obtainable) and the necessary equipment for the conduct of the road-work independent of private supplies. The County Commissioners, accordingly, have purchased 31 mules at a cost of $6500 and an equipment of harnesses, machinery, scoops, carts, wagons, plows, drag harrows, and portable quarters at a cost of $2800.

Among the first pieces of detail work done under the new law was the preparation of a road map showing every road and opening in the county; the kind of opening, whether bridge, terra cotta or iron pipe or trunk, together with length, width or diameter, distance from top of road or bridge to bottom of stream or ditch, its condition and what it could be replaced with when necessary to renew. To each of these openings an arbitrary number was assigned, corresponding to the number on the road map. These have been found to be of decided advantage, especially when

NEW BRIDGE ACROSS CHOPTANK RIVER, GREENSBORO-DENTON ROAD, CAROLINE COUNTY. BUILT UNDER STATE AID LAW.

any bridge or opening was reported to be in bad shape or needed rebuilding. It has been possible to tell at a glance what was necessary to replace the defective part without requiring the time and expense involved in making a long trip to decide on what to put in. As soon as the majority of the small bridges are replaced by pipes, it is proposed to renumber the large openings and to erect number-boards at each large bridge on the same principle as that used in railroad work. Numbers may then be used instead of local names, which often are numerous and varied for the same bridge or culvert.

The actual working season starts on or about April 1, when the teams are taken out of winter quarters and sent into the different sections of the county. Each outfit has a portable house eight feet by twenty feet on wheels, which is fitted up with bunks, kitchen utensils, etc., and in which the men live while away from headquarters. These houses are so arranged with feed boxes and hay racks on the sides and roofs of heavy canvas tarpaulins hooking under eaves, that if necessary one can stable four mules on each side of them. Quite frequently stable room can be found with the different farmers throughout the county. The object gained by having regular camps is the great saving in time and labor in going to and from work, and the saving of the team.

The work consists principally in plowing from the center, since a large percentage of our roads are worn out, after having been scraped over for years. By plowing from the center with furrows from 16 to 20 inches deep, it is possible to turn the old worn-out material under and turn up fresh material, from which to shape up a fairly good road. In scraping the roads, it is the aim to crown them strong, the amount of slope depending altogether on the material worked. At the present, it is costing the county more per mile to work the roads than it did under the old system. This is due to the widening of all roads to a minmum width of 26 feet, the grubbing up of all stump roots, etc., which should have been done when the road was originally built. Under the old system the major portion of the scraping was practically about 16 feet in width, and very little or no attention was paid to the removal of stumps and similar obstructions.

After the roads have been put in good condition in this way, it is the plan to keep them in good order by running over them with log drags (better known as the King Drag), which will keep the ruts filled up.

The County Engineer is also working with a view to eliminating all the small bridges, and has already used 28 carloads of terra cotta and iron pipe, varying from 8 to 72 inches in diameter.

Whether or not the present system is an improvement over the old, both as to results and economy, may be inferred from the following excerpts taken from the Annual Reports of the County Auditor and Grand Jury:

"We have inserted into this report a statement of interest to the taxpayers, the annual report of County Roads Engineer Uhler to the County Commissioners, giving in detail, the cost of material and labor in each district of the County, showing the comparative costs of the old and new system. The improved condition of the roads, at less cost, to our minds, is sufficiently convincing that any tampering or change for the present should be closely guarded by the taxpayers."—Auditor's Report for 1905.

"The annual report of Roads Engineer Uhler to the County Commissioners is again inserted, giving in detail itemized expense for material and road work. We still believe the present system much preferable to the old, and that Engineer Uhler is giving the County energetic and intelligent supervision."—Auditor's Report for 1906.

"The annual report of the County Roads Engineer to the Commissioners is complete in detail, showing cost of work and material for the fiscal year ending June 30, 1907, to be $11,654.98. The Auditor's Report for 1904 shows the cost of the roads under the old system to be $13,617.48, we think a very creditable showing for the new system considering the very greatly improved condition of the roads at $2000.00 less cost."—Auditor's Report for 1907.

As to public highways the Grand Jury said:

"Having eliminated the patronage system of working the county roads, with good results of better roads and at less cost, we advise against any tinkering by amendments or otherwise to the present County road law; that the taxpayers and the County Commissioners give encouragement and aid to the county road engineer to help develop the present system."

"The members of the grand jury heartily concur in the opinion that the roads and bridges of the County show marked improvement under the new system of management and would commend the alertness and industry of the county road engineer. We believe that the change in the local road system promises the most satisfactory results, and have unanimously agreed

FIG. 1.—HOUSTON'S BRANCH ROAD, CAROLINE COUNTY.
BEFORE IMPROVEMENT.

FIG. 2.—HOUSTON'S BRANCH ROAD, CAROLINE COUNTY.
AFTER IMPROVEMENT UNDER STATE AID.

to recommend a thorough trial of this departure to the people of the County. It appears, from our inquiry into the State of the road fund, that this is being handled discreetly and to the best advantage by the engineer and the County Commissioners, and instead of the waste so long complained of under the former order of things, the fund is being effectively expended for the purposes for which it was appropriated."

Besides the maintenance of the present roads under local supervision the county has undertaken the building of permanent highways under the State Aid or "Shoemaker" Road Law. When this law first became operative in 1904, there was considerable opposition to it, the people contending that Caroline County could not afford such costly roads. Such a view arose in part from a lack of appreciation of the advantages of good roads and in part from a misunderstanding of the requirements of the Law. It was at first supposed that only stone roads could be built. After Mr. W. W. Crosby, the Chief Engineer of the State Geological and Economic Survey, showed the falsity of this view by the acceptance of a few miles of shell macadam, a mile of marl road, and finally two miles of sand clay road—built for experimental purposes—the county people realized the latitude allowed by the law and the willingness of the State officials to coöperate in the use of the natural resources of the county. Our people, especially in certain sections of the county, are now becoming so eager for State Aid roads, that they subscribe 25 per cent of their cost instead of 10 per cent, as prescribed by the law. During the past year this county completed one mile of marl macadam road including a 200-foot reinforced concrete bridge at Greensboro, Maryland, which in itself demonstrates the benefits to be derived from the State Aid plan. Without this assistance, it would never have been possible to have built a structure of this character and the people would have resorted to the old and unsatisfactory expedient of a temporary wooden structure.

NEW ALLOTMENT TO THE COUNTIES OF THE STATE APPROPRIATION FOR ROADS, ACCORDING TO THEIR PUBLIC ROAD MILEAGE, EXCLUSIVE OF TURNPIKES.

County.	Mileage.	Allotment.
Allegany	693	$8,806.26
Anne Arundel	521	6,620.44
Baltimore	1,031	13,101.54
Calvert	335	4,256.72
Caroline	706	8,971.44
Carroll	730	9,276.50
Cecil	638	8,107.26
Charles	465	5,908.72
Dorchester	810	10,293.04
Frederick	890	11,309.60
Garrett	940	11,945.08
Harford	822	10,447.52
Howard	378	4,803.06
Kent	427	5,425.90
Montgomery	761	9,670.34
Prince George's	892	11,335.02
Queen Anne's	839	10,661.48
St. Mary's	602	7,649.72
Somerset	515	6,554.04
Talbot	450	5,718.08
Washington	636	8,081.90
Wicomico	825	10,483.62
Worcester	832	10,572.72
Total	15,738	$200,000.00

SUMMARY OF WORK COMPLETED UNDER STATE AID TO HIGHWAYS LAW TO JANUARY 1, 1908.

Surveys made on	168 sections, aggregating	196.36 miles
Plans completed on	146 " "	149.61 "
Estimates made on	146 " "	149.61 "
Estimated cost		$854,186.51
Contracts let or arrangements for construction completed on	88 sections, aggregating	83.44 miles

WORK DONE UNDER SAME.

Bridges built	30	
Culverts "	297	
Excavation	211,024	cu. yds.
Cement masonry	1,122.24	" "
Concrete "	751.63	" "
Reinforced "	603.60	" "
Brick "	92.50	" "
Underdrain	19,107.00	lin. ft.
Clay pipe laid less than 12 in.	358.00	" "
" " " " " " " relaid	26.00	" "
Clay pipe laid 12 in.	315.00	" "
" " " 12 " relaid	183.00	" "
" " " 15 "	1,408.00	" "
" " " 15 " relaid	146.00	" "
" " " 16 "	3.00	" "
" " " 18 "	1,094.00	" "
" " " 20 "	84.00	" "
" " " 20 " relaid	6.00	" "
" " " 22 "	8.00	" "
" " " 22 " relaid	18.00	" "
" " " 24 "	672.00	" "
" " " 24 " relaid	7.00	" "
" " " 30 "	87.00	" "
Cast iron pipe laid 12 in.	1,224.00	" "
" " " " 12 " relaid	20.00	" "
" " " " 14 "	1,000.00	" "
" " " " 15 "	38.00	" "
" " " " 15 " relaid	22.00	" "
" " " " 16 "	180.00	" "
" " " " 18 "	144.00	" "
" " " " 24 "	82.00	" "
" " " " 24 " relaid	20.00	" "

SURFACING.

Broken stone	357,877	sq. yds.
Marl	5,946	" "
Gravel	41,290	" "
Shell	27,956	" "
Sand and clay	5,400	" "

Certification to the State Comptroller has been made on 56 sections of 51.81 miles, amounting to	$348,776.91
About 22 miles additional are approaching completion, amounting approximately to	140,000.00
About 10 miles additional are in various stages of construction, amounting approximately to	70,000.00

TABLE SHOWING CONTRACT PRICES PAID FOR WORK DURING 1905, 1906, 1907.

County.	Road.	No. of Contract.	Grading per cu. yd. Excava. all kinds.	Grading per cu. yd. Barrow Exca.	Masonry per cu. yd. Cem. R.	Masonry per cu. yd. Con.	Masonry per cu. yd. Reinf. Con.	Pipe Culverts. "Clay" per lin. ft. 12″	"Clay" 15″	"Clay" 18″	"Clay" 24″	"Clay" 30″	"Cast Iron" per lin. ft. 12″	"Cast Iron" 14″	"Cast Iron" 16″	"Cast Iron" 18″	Macadam per sq. yd. 6″	Macadam per sq. yd. 8″	Gravel per sq. yd. 10″ ctr. 8″ sides.	Shell per sq. yd. 8″ ctr. 6″ sides.	Underdrain. Per lin. ft.
Allegany.	Baltimore Pike	73	$.55	$.55	$7.70	....	....	....	....	....	....	$3.30	....	...	....	....	$.88	....	....	....	....
	Barrelville No. 1	18	.55	....	4.25	....	....	...	$.75	$.95	$1.80	....	....	$2.25	....	....	.35	....	....	....	....
	" No. 6A	144	.66	.66	6.60	$8.80	$13.20	....	....	....	....	....	....	2.75	....	....	.55	$.72	.. .	....	$.50
	Bedford	4	.60	....	4.00	....	....	$.55	.74	$.88	..	....	....	1.13	....	.. .	.38	.30	....	....	....
	Lonaconing	48	.55	.55	5.50	5.50	13.75	.70	88	1.22½	....	3.85	$2.20	....	....	$4.10	.72	.85	....	....	....
Baltimore.	Chatsworth Ave	11	.45	...	6.00	....	....	....	....	....	....	....	....	2.37½	....	....	.63	....	....	....	....
	Eccleston No. 1	133A	.50	....	....	8.00	16.00	.70 *.40	.95 *.45	1.10 *.50	....	....	2.75	....	$4.50	....	.75	.95	....	....	.45
	Falls No. A	151A	.65	....	9.00	....	...	....	1.50	....	....	....	2.50	....	....	....	1.20	1.30	....	....	....
	Garrison No. 1	16	.47	.57	7.00	....	10.50	....	.75	....	....	....	....	....	....	....	.63	....	....	....	....
	" No. 2	114	.70	....	9.00	14.00	...	....	....	.95	....	....	....	....	....	....	.95	....	....	....	.45
	" No. 3	23	.60	....	8.00	8.00	10.00	....	....	1.50	....	....	....	....	....	....	.60	....	....	...	....
	Gwynn Oak Ave	66	.60	....	6.50	....	12.00	....	.70	....	....	....	....	3 50	....	....	.60	.88	....	....	.40
	O'Donnell St	41	.60	.60	....	....	6.50	....	....	....	....	....	....	...	....	....	.78½	....	....	....	....
	Park Heights Ave. No. 1	84	.60	.60	8.00	....	12.00	.60 *.25	....	....	1.50 *.50	....	. .	....	....	....	.80	.98	...	....	.40
	" " " No. 2	86A	.70	.70	9.00	....	15.00	.70	.90	....	1.60	....	2.50	....	....	....	.90	1.05	....	....	.45
	Philadelphia	44	.60	....	.. .	....	....	....	....	....	....	....	....	....	....	...	.78	....	....	....	....
	Seminary Ave. No. 1	46	.65	....	7.00	....	15.00	....	....	....	....	....	....	...	4.00 *1.00	....	.76	....	....	....	....
	Valley No. 4A	37A	.80	....	8.00	8.00	....	.70	.95	....	....	....	2.75	....	4.50	....	.75	.95	....	... .	.45
	White Hall	54	.65	....	8.00	....	11.00	....	....	....	....	....	....	....	....	....	.70	....	....	...	....
	Wilkens Ave. No. 1	7	.40	....	4.00	..	10.00	....	.60	....	....	....	....	....	....	....	.55	....	....	....	....
	" " No. 2	80	.60	1.00	6.00	....	....	....	....	....	....	....	3.00	....	...	....	.75	....	....	....	.45
Caroline.	Bloomery	153	.27½	....	....	8.25	13.00	...	1.00	1.20	2.10	....	2.40	..	....	....	....	....	....	$.65	....
	Greensboro-Boyce's Mill	128	.40	....	....	10.00	....	....	....	....	2.10	....	....	....	....	....	....	....	†$.15	...	.10
	Denton-Greensboro	113	.34	.34	....	10.00	....	..	....	....	2.00	....	....	....	....	....	....	...	....	.391	....
	Houston's Branch No. 1	60	.24	....	....	....	....	....	....	....	....	....	1.30	....	....	....	...	....	....	.45	....
	" " No. 2	93	.28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.57	....
Carroll.	Eldersburg	29	.59	...	4.50	....	....	....	....	1.75	3.00	....	....	....	....	....	.48	....	....	....	....
	Mt. Airy	18	.30	....	5.00	....	....	....	1.20	....	....	....	2.48	....	....	....	.47	....	....	....	....
	Nicodemus	82	.40	....	7.70	....	. .	....	1.27	....	....	....	2.48	3.08	....	....	.60	....	....	....	....
Cecil.	Aiken Ave	12	.40	....	4.50	....	....	*.25	.60	....	....	....	....	.	....	...	....	.50	....	....	....
	Rising Sun, Farmington	6	.33	....	4.00	....	....	....	.68	....	....	....	....	1.62½	....	....	.50	.70	....	....	.16

TABLE SHOWING CONTRACT PRICES PAID FOR WORK DURING 1905, 1906, 1907.—*Continued.*

Dorchester.	Allen's Corner No. 1	27	$.20	....	....	$7.00	....	....	....	*$.15	....	....	....	....	....	....	....	....	....	$.44	....
	Brookview	89	.28	....	....	....	....	....	....	....	$1.00	....	....	$2.00	....	....	....	....	....	.60	....
	Williams	62	.25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.48	....
Fred.	Braddock	65	.69	$.48	$4.00	....	....	....	....	1.50	....	....	$3.00	....	....	....	$.60	....	....	....	....
	Monrovia	8	.40	....	3.00	....	....	....	$.75	1.00	....	....	....	....	....	....	.45	$.60	....	....	$.10
Harford.	Darlington	96	.60	....	6.00	....	$12.50	....	1.00	1.25	2.50	....	....	3.50	....	....	.70	.75	....	....	.45
	Hickory E	94 E	.70	....	6.00	....	....	....	....	....	2.50	....	2.25	....	....	....	.55	.70	....	....	....
	" F	94 F	.70	....	6.00	....	....	....	....	1.00	....	....	2.25	....	....	....	.55	.70	....	....	....
Howard.	Baltimore-Washington	14A	.35	....	7.00	7.00	18.00	....	....	....	.90	....	....	....	....	....	.58	....	....	....	....
	L. Sykesville No. 1	10	.85	....	5.00	....	12.00	....	....	....	....	....	....	....	....	....	.45	....	....	....	....
	" " No. 2	130	.65	....	6.00	6.00	....	....	.75	....	....	....	2.50	....	....	....	.75	.95	....	....	....
Montgomery.	Barnesville	92	.45	....	6.00	....	....	*$.75	1.25	1.50 *1.00	....	....	*1.50	....	....	....	.65	.65	....	....	....
	Blair No. 1	56	.50	....	5.00	....	....	....	....	2.00	....	....	2.50	3.00	....	....	.60	....	....	....	....
	" No. 2	67	.40	....	....	6.50	13.50	....	2.50	3.00 *1.50	....	....	....	....	....	....	.65	.70	....	....	....
	Bradley Lane	142	.45	....	6.92	6.92	....	....	.65	....	....	....	1.75	1.75	....	....	1.12	1.12	....	....	.25
	Germantown No. 1	21	.30	....	4.00	....	....	....	.75	....	....	....	2.00	....	....	....	.50	....	....	....	....
	" No. 2	70	.45	....	6.00	....	....	....	....	....	....	....	....	3.00	....	....	.65	.65	....	....	....
	Laytonsville No. 1	9	.31⅜	....	4.35	....	....	....	....	1.00	....	....	....	3.08	....	....	.42	.42	....	....	.16
	" No. 2	76	.50	....	6.00	....	....	....	....	....	....	....	....	3.00	....	....	.60	.80	....	....	....
	Old Baltimore	39	.45	....	4.00	....	....	....	.75	1.00	....	$2.00	....	....	....	....	.55	....	....	....	....
	" Frederick	53	.45	....	6.00	....	....	....	....	....	....	....	2.50	2.50	....	....	.60	.70	....	....	.60
	" Georgetown	45	.50	....	6.00	....	....	....	....	....	....	....	3.00	....	....	....	.59	....	....	....	....
	Poolesville No. 1	30	.38	....	3.50	....	....	....	.75	....	1.75	*1.25	....	....	....	....	.46	....	....	....	....
	" No. 2	72	.40	....	3.75	....	....	....	1.00	....	....	....	2.50	....	....	....	.65	.65	....	....	....
Prince George.	Baltimore-Washington	36	.50	....	6.00	6.00	....	*.45	.85	1.10 *.60	....	....	....	....	....	....	....	.65	....	....	....
	Livingston No. 1	20	.50	....	6.00	6.00	12.50	....	....	....	....	....	....	3.00	....	....	....	....	$.75	....	....
	" No. 2	85	.65	....	....	8.00	....	....	.60	....	....	....	....	....	....	....	....	....	.40	....	....
	Marlboro No. 1	5	.50	....	6.00	6.00	....	....	.85	1.10	....	1.90	....	....	....	....	....	....	ϕ.65	....	....
	" No. 2	88	.45	....	....	10.00	....	1.25 *.50	1.50	1.70	....	ω	....	....	....	....	....	....	.40	....	....
	No. 3	91	.45	....	....	10.00	....	....	1.50 *1.00	....	....	....	2.50	....	....	....	....	....	.40	....	.40
	Queen Anne	90	.45	....	....	10.00	....	....	....	....	....	2.50	2.50	....	....	....	....	....	.34	....	.25
Wash.	Clearspring	1	.55	.22½	....	2.40	....	....	.75	.85	....	....	1.42	....	....	....	....	.22	....	....	....

I 6″ and 8″ marl surface.
* Relaid.
ϕ 5″ gravel and 3″ stone.
† Sand and clay construction.

ω { 22″ @ 2.00
22″ * 1.00
36″ @ 4·00

4

COST OF COMPLETED ROADS SHOWING SEPARATION OF COSTS ON VARIOUS KINDS OF WORK COMPLETED.

County.	Road.	Sq. yds. of Surfacing.	Length in Miles.	Cost. Grading.	Cost. Culverts. Bridges.	Cost. Under-drains.	Cost. Surfacing.	Cost. Miscel-laneous.	Cost. Total.	Remarks.
Allegany.	Baltimore Pike	2.848	.35	$1.121.25	$888.57	....	$3,006.24	$32.90	$4,998.96	
	Barrelville No. 1	6,998	1.00	1,885.95	277.80	....	3,582.74	70.80	5,767.29	
	" No. 2	1,867	.27	277.50	141.14	....	1,076.85	98.33	1,593.82	
	" No. 4	2,024	.29	351.30	44.44	....	1,214.52	89.20	1.699.46	
	" No. 6A	4,628	.66	3,514.88	382.32	$99.56	2,583.40	53.70	6,633.86	
	Bedford	7,600	1.08	1,579.20	423.17	1,156.35	4,276.81	147.04	7,582.57	
	Lonaconing	5,653	.75	4,813.00	823.76	103.13	4,939.55	401.99	10,581.43†	Of this $1069.02 was paid by R. R.
Baltimore.	Boyce Ave	5,200	.73	984.50	628.70	214.00	4,214.41	58.62	6,050.23	
	Chatsworth Ave	5,451	.78	1.169.23	237.45	326.12	3,434.18	73.94	5,240.87	
	Garrison No. 1	6,424	.86	1,618.92	687.94	108.13	4,050.22	388.28	6,848.49	
	" No. 2	3,174	.50	1,463.00	734.20	90.00	3,135.72	226.37	5,649.29	
	" No. 3	4,983	.70	1.013.27	230.64	....	3,377.70	309.85	4,931.46	
	Gwynn Oak Ave. No. A	5.848	.72	1.914.00	86.65	763.20	3,505.80	106.15	6.375.80	
	O'Donnell St	5,308	.66	1.331.40	379.38	...	4,166.78	399.70	6.277.26	
	Park Heights Ave. No. 1	7,078	.85	1,617.00	751.76	96.40	5,694.18	133.19	8,292.53	
	Philadelphia	2,800	.34	262.20	....	....	2,184.00	38.23	2,484.43	
	Seminary Ave	7,993	1.13	1,992.90	1.281.80	...	6,071.48	77.35	9,423.53	
	Valley 4A	8,927	1.27	3,759.86	395.83	....	7,125.59	75.42	11,356.70	
	White Hall	3,867	.50	2,747.56	457.60	32.59	3,167.77	215.51	6.621.03	
	Wilkens Ave. No. 1	16,600	2.35	1 107.20	594.67	....	6,868.00	165.99	8.735.86	
	" " No. 2	70,900	.97	992.05	189.01	160.20	5,657.13	130.65	7,129.04	
Caro-line.	Denton-Greensboro	5,946	.82	1,076.44	7.316.95	....	2,318.94†	233.30	10,945.63	
	Houston's Branch No. 1	5,282	1.00	278.40	....	....	2,376.00*	68.00	2,722.40	
	" " No. 2	2,000	.38	170.80	....	....	1,140.00*	34.25	1,345.05	
Car-roll.	Eldersburg	7,476	1.02	3,138.80	2,496.62	305.64	3,731.07	148.57	9,820.70	
	Mt. Airy	4,027	.57	486.00	194.20	....	1,892.69	71.10	2,643.99	
Cecil.	Aiken Ave	10,817	1.00	670.00	64.93	....	4,932.71ω	52.00	5,719.64	
	Rising Sun, Farmington	7,893	1.10	508.17	150.96	468.22	4,418.07	16.50	5,561.92	

COST OF COMPLETED ROADS SHOWING SEPARATION OF COSTS OF VARIOUS KINDS OF WORK COMPLETED.—Continued

Dorchester.	Allen's Corner	7,800	1.50	$620.00	$73.10	....	$3,432.00*	$76.00	$4,201.10	
	Brookview	5,450	1.00	574.00	308.00	....	3,270.00*	50.00	4,202.00	
	Williams No. 2	2,826	.53	271.25	....	....	1,356.48*	29.50	1,657.23	
Fred.	Braddock	2,719	.37	882.51	92.10	....	1,631.40	41.00	2,647.01	
	Monrovia	10,183	1.46	2,894.16	2,194.59	$252.42	4,784.43	125.46	10,251.06	
Harford.	Churchville No. 1	7,467	1.06	1,097.43	169.70	....	4,499.33	46.50	5,812.96	
	" No. 2	14,800	2.10	1,759.04	450.08	....	8,869.94	209.33	11,288.39	
	" No. 3	6,000	.85	398.50	78.78	....	3,129.76	57.89	3,664.93	
	Earlton	12,712	1.80	1,794.25	821.69	693.00	7,647.91	64.50	11,021.35	
	Fallston No. 1	6,844	.97	1,279.00	246.89	....	6,265.37	60.50	7,851.76	
	" No. 2	9,690	1.37	3,349.50	341.00	....	7,656.23	226.05	11,572.78	
	Forest Hill	6,133	.87	1,025.58	407.77	....	3,535.84	37.50	5,006.69	
	Hickory No. F	7,547	1.06	2,597.00	454.20	....	4,278.43	58.70	7,388.33	
Howard.	Baltimore-Washington	3,733	.53	428.40	173.64	....	2,165.14	93.40	2,860.58	Less $150 for delay, $2,710.58
	Lower Sykesville	3,709	.53	2,065.00	359.20	....	1,669.05	192.35	4,785.60	
Montgomery.	Germantown No. 1	7,040	1.00	811.50	178.25	....	3,520.00	60.80	4,570.55	
	" No. 2	3,600	.51	666.00	275.76	....	2,840.00	38.95	3,820.71	
	Laytonsville No. 1	7,040	1.00	995.24	411.27	....	3,907.70	60.80	5,375.01	
	" No. 2	7,227	1.00	1,071.00	350.80	....	4,769.10	64.95	6,255.85	
Prince George.	Baltimore-Washington No. 1	7,846	.96	2,086.50	300.73	718.19	5,232.47	65.00	8,397.89	
	Livingston No. 1	6,933	.98	1,272.50	305.95	....	5,321.88ω	229.18	7,129.01	
	" No. 2	2,984	.41	934.02	90.64	....	1,505.99ω	83.76	2,614.41	
	Marlboro No. 1	9,200	1.30	1,976.00	216.63	....	6,197.47	43.30	8,433.40	Less $150 for delay, $8,283.40
Talbot.	Bayside	4,600	.87	585.00	294.50	....	2,630.00	75.42	3,584.92	
Wash.	Clearspring	13,912	2.00	4,546.67	230.88	....	3,091.62	146.90	8,016.07	
Worcester.	Berlin-Hayes Landing	8,000	1.12	1,436.42	598.23	....	7,540.70	76.00	9,651.35	
	Good Will No. 1	7,067	1.00	543.16	357.30	....	7,097.54	62.00	8,060.00	
	Mile Post	7,480	1.01	403.04	57.42	....	6,983.94	67.25	7,511.65	
		429,994	51.81	$79,652.45	$30,149.59	$5,582.15	$228,421.72	$6,359.92	$350,165.83	

† Marl. * Shell. ω Gravel.

TABLE SHOWING ROADS ON WHICH WORK HAS BEEN DONE DURING 1905, 1906 & 1907, THE INSPECTORS ON SUCH WORK, TOGETHER WITH DATES OF BEGINNING AND ENDING.

County.	Name of Road.	Sec.	Name of Inspector.	Date of Contract.	Date of Beginning.	Date of Ending.
Allegany	Baltimore Pike	1	W. A. Smith	4-5-07*	4-5-07	8-27-07
"	Barrellville	1	E. D. Digges	8-18-05	8-18-05	7-1-06
"	"	2	P. C. Dennis	6-26-06*	6-26-06	10-10-06
"	"	4	P. C. Dennis	7-25-06*	7-25-06	10-11-06
"	"	6A	A. F. Hutchins	6-26-07*	6-26-07	11-1-07
"	Bedford	1	L. N. Whitcraft	6-9-05	6-21-05	5-20-06
"	Lonaconing	1	L. N. Whitcraft	10-28-05	11-1-05	7-30-07
Baltimore	Boyce Ave.	1	W. W. Offutt	5-30-07*	5-30-07	8-29-07
"	Chatsworth Ave.	1	J. C. Schenck H. W. Yellott R. W. Owens	7-6-05	8-10-05	9-10-06
"	Eccleston	1	C. A. Tenny	7- -07	10-23-07	....
"	"	2	C. A. Tenny	7- -07	12-6-07	....
"	Falls	A	J. G. Lewis	7-18-07	8-5-07	11-14-07
"	Garrison	1	C. P. Smith J. N. Mackall R. E. Hamilton J. C. Schenck R. W. Owens	7-6-05	7-19-05	9-1-06
"	"	2	R. W. Owens	4-18-07	5-11-07	9-4-07
"	"	3	C. P. Smith J. N. Mackall R. E. Hamilton J. C. Schenck R. W. Owens	7-21-05	8-28-05	9-25-06
"	Gwynn Oak Ave.	1	H. J. Hebb J. B. Fink	5- -06	5-21-06	7-15-07
"	" " "	B	H. J. Hebb J. B. Fink A. M. Vail	7-11-07	9-19-06	....
"	O'Donnell St.	1	J. R. Strange G. T. Eager P. C. Dennis	9-14-05	9-26-05	6-20-06
"	Park Heights Ave.	1	H. W. W. Peploe R. W. Owens	9-5-06	9-1-06	6-7-07

TABLE SHOWING ROADS ON WHICH WORK HAS BEEN DONE DURING 1905, 1906 & 1907, THE INSPECTORS ON SUCH WORK, TOGETHER WITH DATES OF BEGINNING AND ENDING.—Continued.

Baltimore	Park Heights Ave	2A	R. W. Owens	7-24-07	8-22-07	....
"	Philadelphia	1	G. T. Eager J. R. Strange P. C. Dennis	9-14-05	10-16-05	1-22-06
"	Seminary Ave	1	A. A. Jackson J. N. Mackall G. T. Eager F. E. Schnepfe L. N. Whitcraft	10-5-05	10-5-05	9-1-06
"	Valley	4A	C. S. Gale C. A. Tenny	7-25-07	8-2-07	12-11-07
"	"	7	J. S. Gorsuch V. G. Corrie	7-5-07*	7-5-07	....
"	White Hall	1	J. A. Reynolds	8-30-06	8-27-06	11-9-07
"	Wilkens Ave	1	J. L. Houston F. D. Christlief	6-16-05	7-5-05	1-17-06
"	" "	2	R. W. Owens	8-2-06	8-6-06	1-11-07
Calvert	Solomon's Island	1	J. N. Mackall	10-1-06	10-1-06	10-17-06
Caroline	Bloomery	1	F. D. Christhilf	10-15-07	11-4-07	....
"	Denton-Greensboro	1	C. A. Tenny	12-18-06	1-5-07	9 29-07
"	Greensboro-Boyce's Mill	1	W. L. Norton A. F. Hutchins	9-24-07	10-8-07	....
"	Houston's Branch	1	F. W. Seth	10-5-05	11-8-05	1-25-06
"	" "	2	W. H. Smith	11-30-06	11-8-06	12-20-06
Carroll	Eldersburg	1	J. H. Starkey E. T. Hayman G. T. Whelton S. M. Hendricks	10-5-05	11-6-05	3-27-07
"	Mt. Airy-Ridgeville	1	S. M. Hendricks	7-13-05	9-6-05	2-1-06
"	Nicodemus	1	R. R. Dennis	8-12-07	8-26-07	....
Dorchester	Allen's Corner	1	F. W. Seth	11-14-05	11-9-05	1-31-06
"	Brookview-Rhodesdale	1	F. E. Schnepfe	12-4-06	2-2-07	5-8-07
"	Williams	1	J. C. Gittings, Jr.	2-18-06	2-20-06	3-23-06

TABLE SHOWING ROADS ON WHICH WORK HAS BEEN DONE DURING 1905, 1906 & 1907, THE INSPECTORS ON SUCH WORK, TOGETHER WITH DATES OF BEGINNING AND ENDING.—Continued.

County.	Name of Road.	Sec.	Name of Inspector.	Date of Contract.	Date of Beginning.	Date of Ending.
Frederick..................	Braddock.....	1	F. D. Christhilf............	5-7-06	5-1-06	11-19-06
"	New Market-Monrovia....	1	W. White.................. J. B. Fink.... .... E. D. Digges..............	6-7-05	7-19-05	9-25-06
Harford.....................	Churchville	2	P. C. Dennis................	*	....	9-15-06
"	"	3	J. J. A. Krentzlin..........	5-14-06*	5-14-06	12-29-06
"	Darlington..................	1	O. M. Bosley................	4-22-07	5-21-07	12-3-07
"	Fallston	2	W. H. Smith.................	5-15-06*	5-15-06	11-1-06
"	Hickory	E	H. M. Clark..................	7-1-07	10-14-07	....
	"	F	H. M. Clark..................	7-1-07	7-23-07	11-21-07
Howard...............	Baltimore-Wash. Pike....	1	F. E. Schnepfe........... A. M. Vail	8-22-05	9-14-05	8-1-06
"	Lower Sykesville	1	H. T. Ruhl................. G. T. Whelton .... J. C. Gittings, Jr......... W. F. Lankford...........	7-18-05	8-11-05	12-21-06
"	" "	2	F. G. Latham .... E. L. Micheau............	6-11-07	7-1-07	....
Montgomery	Barnesville.................	1	W. F. Lankford.......... A. R. Adamson....... ...	6-4-07	11-22-06	....
"	Blair.......	1	C. W. Henderson .... R. H. Dixon, Jr.......... J. A. Reynolds...........	10-23-06	5-18-07	....
"	"	3	E. D. Digges .... R. H. Dixon, Jr.......... J. A. Reynolds........ ...	10-23-06	11-12-06	....
"	Bradley Lane	1	U. D. Rich...................	7-30-07	1-11-07	....
"	Old Frederick..............	1	J. H. Starkey............ W. White............ ...	6-19-06	7-19-06	12-23-06
"	Germantown...............	1	J. J. A. Krentzlin........ E. T. Hayman............ A. R. Adamson..........	7-25-05	9-27-05	10-20-06
"	"	2	A. R. Adamson............	8-10-06	6-20-06	12-10-06
"	Laytonsville	1	S. M. Hendricks...........	6-13-05	7-6-05	5-1-06
"	"	2 & 3	O. M. Bosley..	8-7-06	9-26-06	5-16-07

TABLE SHOWING ROADS ON WHICH WORK HAS BEEN DONE DURING 1905, 1906 & 1907, THE INSPECTORS ON SUCH WORK, TOGETHER WITH DATES OF BEGINNING AND ENDING.—Continued.

Montgomery	Old Baltimore	1	J. B. Beall W. White J. H. Starkey	10-17-05	2-26 06	....
"	Old Georgetown	1	F. E. Schnepfe W. R. Beckett S. M. Hendricks	11-8-05	11-12-05	....
"	Poolesville	1	W. White W. F. Lankford A. R. Adamson	8-24-05	1-2-06	....
"	"	2	W. F. Lankford	5-21-06	8-3-07	....
Prince George	Baltimore-Washington	1	J. H. Starkey E. T. Hayman	11-26-05	9-8-05	7-1-06
" "	Livingston	1	J. I. Wisner E. T. Hayman	9-5-05	9-20-05	8-7-06
" "	"	2	E. H. Wroe	9-11-06	10-8-06	7-13-07
" "	Marlboro	1	H. Lanahan J. N. Mackall J. B. Fink E. T. Hayman	6-22-05	6-26-05	6-1 06
" "	"	2	F. E. Schnepfe R. R. Dennis C. W. Shelton	6-18-07	7-13 07	....
" "	"	3	C. W. Shelton	6-18-07	8-28-07	....
" "	Queen Anne	1	F. E. Schnepfe	9-18-06	6-6-07	..
Talbot	Bayside	1	R. H. Blain J. C. Gittings, Jr	10-17-05*	10-17-05	2-1-06
Washington	Clearspring	1	E. T. Hayman F. E. Schnepfe H. M. Clark	6-27-05	7-11-05	7-11-07
Worcester	Berlin-Hayes Landing	1	L. N. Whitcraft E. H. Wroe	4-4-07*	4-4-07	9-19-07
"	Good Will	1	A. M. Vail	4-8-07*	4-8-07	8-9 07
"	" "	2	R. H. Dixon, Jr. A. M. Vail	....	8-12-07	....
"	Mile Post	1	J. C. Gittings, Jr. E. D. Digges	6-6-06*	6-6-06	10-27-06
"	Purnell's Mill Pond	1	E. H. Wroe	9-20-07*	9-20-07	....

*Contractor: County. ϕ Abandoned by county. ω Work stopped.

TABLE SHOWING SECTIONS OF STATE ROAD NO. 1 ON WHICH WORK HAS BEEN DONE DURING 1906 & 1907, THE INSPECTORS ON SUCH WORK, TOGETHER WITH DATES OF BEGINNING AND ENDING.

County.	Road.	Sec.	Inspector.	Date of Contract.	Date of Beginning.	Date of Ending.
Howard	State Road No. 1	3N	L. N. Whitcraft C. O. Boyd	8-9-06	8-22-06	....
"	" " " "	5N	P. C. Dennis F. D. Christhilf J. J. A. Krentzlin	11-6-06*	11-6-06	12-28-07ϕ
"	" " " "	7N	P. C. Dennis F. D. Christhilf U. D. Rich	1-29-07*	1-29-07	12-21-07ϕ
Prince George	" " " "	4S	L. N. Whitcraft C. P. Dennis F. D. Christhilf	8-28-06*	8-28-06	11-28-07ϕ
" "	" " " "	3A	F. E. Schnepfe J. T. Baden	4-26-07	5-9-07	11-14-07
" "	" " " "	12A	J. T. Baden	5-7-07	8-5-07	12-13-07ϕ

* Contractor: State of Maryland.

ϕ Work stopped temporarily.

STATEMENT OF WORK DONE UNDER THE STATE AID ROAD LAW DURING 1905, 1906, 1907.

County.	Roads applied for.	Surveyed.	Preliminary Estimates Furnished.		Contracts Let.		Roads Completed.				Total Cost.	Paid by the State.		Roads now under Construction.
	Miles.	Miles.	Miles.	Amount.	Miles.	Amount.	1905.	1906.	1907.*	Totals.		1906.†	1907.	Miles.
Allegany	11.38	18.91	10.18	$70,730.64	4.40	$38,857.39	....	2.64	1.76	4.40	$41,888.98	$9,651.62	$11,981.17	....
Anne Arundel	12.07	7.77	3.10	16,223.01	....	....	....	....	....	....	....	....	....	....
Baltimore	85.48	37.45	32.81	234,024.44	19.38	120,089.97	....	6.82	5.54	12.36	106,601.91	27,610.29	82,765.47	*6.33
Calvert	2.00	1.00	.94	10,186.28	....	....	....	....	....	....	....	....	....	....
Caroline	10.32	8.14	7.14	34,449.64	6.02	29,982.93	....	1.38	.82	2.20	17,241.41	1,662.68	8,072.19	3.82
Carroll	4.28	3.75	3.44	23,392.80	2.59	18,568.09	....	.57	1.02	1.59	13,746.66	2,527.91	4,986.41	1.00
Cecil	9.10	7.84	5.22	28,663.51	2.10	11,281.56	2.10	....	....	2.10	12,884.88	6,744.10	....	....
Charles	1.00	1.05	.95	8,476.05	....	....	....	....	....	....	....	....	....	....
Dorchester	9.55	3.80	3.70	21,855.18	3.03	10,060.33	....	2.03	1.00	3.03	11,144.99	3,582.12	2,582.71	....
Frederick	4.17	4.19	2.80	18,740.43	1.83	12,898.07	....	1.83	....	1.83	14,270.77	6,498.23	1,314.57	....
Harford	23.16	22.49	18.30	95,565.29	16.03	98,495.44	4.70	4.32	1.06	10.08	70,010.01	15,072.01	18,186.47	2.03
Howard	8.74	7.74	4.72	38,738.67	1.56	11,898.18	....	1.06	....	1.06	8,463.47	1,882.85	2,833.08	.50
Montgomery	19.44	19.26	18.92	35,554.78	12.36	84,007.56	....	2.51	1.00	3.51	26,137.15	9,396.84	7,089.26	8.85
Prince George's	12.44	11.10	10.24	58,463.34	6.14	37,818.80	....	3.24	.41	3.65	29,838.26	14,060.77	827.44	2.49
Queen Anne's	23.57	14.57	7.18	27,575.00	....	....	....	....	...	....	....	....	...	....
St. Mary's	7.50	7.50	1.00	2,986.17	....	....	....	....	...	....	....	....	....	....
Talbot	3.00	1.46	1.71	7,019.87	1.46	5,691.42	....	.87	....	.87	3,986.89	2,117.57	....	.59
Washington	7.31	7.31	4.63	25,155.44	2.00	8,016.07	....	....	2.00	2.00	9,070.78	602.96	4,459.78	....
Wicomico	6.00	6.00	3.97	23,658.58	....	....	....	....	....	....	....	....	....	....
Worcester	10.53	10.53	9.21	73,227.44	5.13	41,747.26	....	1.01	2.12	3.13	29,807.36	1,004.93	16,150.58	2.00
Totals	271.04	196.36	149.61	$854,186.51	84.08	$528,908.07	6.80	28.28	16.73	51.81	$396,093.52	$102,304.88	$111,199.08	27.61

* The work carried on during 1907 should include as well the roads under construction, the total mileage of which is shown in the last column of this table.

† The amounts given in this column include a few preliminary payments made in 1905 for the work of that year.

RESULTS OF TESTS OF ROAD MATERIAL

OBTAINED BY THE HIGHWAY DIVISION, MARYLAND GEOLOGICAL SURVEY, FROM JANUARY 1, 1906, TO JANUARY 1, 1908.

BALTIMORE COUNTY.

Book.	No. of Test.	Material.	Quarry.	Location.	Coef. of Wear.	Cementation coef.
3	279	Serpentine	......	White Hall	13.50	166
	280	Trap	......	nr. Franklin Road	16.40	42
	281	Serpentine	......	Bare Hills	4.70	253
	282	Trap	......	Woodlawn	6.00	34
	283	Trap	......	Woodlawn	17.00	18
	284	Trap	......	Belair Road	6.70	65
	287	Trap	Chas. Bowen's	Towson	10.00	60
	288	Diabase	Advance	Belair Road and Herring Run	7.15	34
	293	Gabbro	H. Sauter's	nr. Franklin Road	16.60	16
	294	Gabbro	Gatch's	Gardenville	16.00	15
	297	Trap	Md. Quarry Co.	nr. Franklin Road	13.50	19
	298	Trap (Diabase)	Martin's	Catonsville	13.80	...
4	301	Serpentine	......	White Hall	14.29	52
	302	Granite	Fellowship	Towson	10.20	11
	303	Trap	......	White Hall	8.90	...
	304	Trap	Gelston's	Franklin Road	8.33	11
	308	Gneiss	Malvern	......	14.90	20
	309	Serpentine	McColgan's	Bare Hills	4.59	...
	310	Serpentine	McColgan's	Bare Hills	5.36	...
	311	Gneiss	......	nr. Stevenson	5.71	...
	312	Trap	H. Sauter's	nr. Franklin Road	14.70	...
	314	Trap	Gelston's	nr. Franklin Road	17.40	...
	316	Limestone	......	Rockland	7.78	...
	317	Limestone	Gen. Agnus'	Green Spring Valley	12.10	...

CARROLL COUNTY.

Book.	No. of Test.	Material.	Quarry.	Location.	Coef. of Wear.	Cementation coef.
3	289	Gneiss	......	Carrolton	6.15	30

CECIL COUNTY.

Book.	No. of Test.	Material.	Quarry.	Location.	Coef. of Wear.	Cementation coef.
3	300	Meta Rhyolite	Susquehanna Broken Stone Co.	Frenchtown	8.70	67

FREDERICK COUNTY.

Book.	No. of Test.	Material.	Quarry.	Location.	Coef. of Wear.	Cementation coef.
3	285	Trap	......	Frederick	8.20	69

HOWARD COUNTY.

Book.	No. of Test.	Material.	Quarry.	Location.	Coef. of Wear.	Cementation coef.
3	290	Gneiss	J. M. Mount's	Sykesville	10.00	80
4	305	Trap	Harez Farm	Waterloo	8.51 8.95	59 61

MONTGOMERY COUNTY.

Book.	No. of Test.	Material.	Quarry.	Location.	Coef. of Wear.	Cementation coef.
3	296	Trap	Standard Stone and Lime Co.	Dickerson	25.00	63
4	318	Serpentine	O. B. Williams	nr. Laytonsville Road	10.50	...

WASHINGTON COUNTY.

3	291	Limestone	Pinesburg Quarry Co.	Pinesburg	6.25	33
4	307	Limestone	Pinesburg Quarry Co.	Pinesburg	10.50	21.6
	315	Medina Sandstone	......	Cumberland Narrows	8.33	...

MISCELLANEOUS

3	286	Limestone	......	Lemoyne	9.50	75
	295	Gneiss	Independent Quarry Co.	Harford Road (Balto.)	10.53	39
	299	Limestone (Dolomitic)	Chas. Werner & Co.	Wilmington, Del.	6.00	128
4	306	Limestone	Thomasville Lime and Stone Co.	Thomasville, Pa.	7.70	26
	313	Medina Sandstone	Orleans Co. Quarry Co.	...... N. Y.	11.00	...
	319	Limestone	......	......	9.70	...

TABLE SHOWING RESULTS OF TESTS OF PAVING BRICK OBTAINED AT THE LABORATORY OF THE HIGHWAY DIVISION OF THE MARYLAND GEOLOGICAL SURVEY DURING 1906 & 1907.

Number.	Name.	Color.	Percentage Lost in Rattler 1800 Revolutions. Percentage Lost by Each Brick in a Test. No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	Average.	Date of Tests.	Made at the Request of	Samples Selected by
416	Pittsburg 4" Block	Red	26	28	31	34	34	44	46	53	..	..	36	1-27-06	City Engr., Baltimore.	Engineer.
417	Montello Block	Dark Red	10	12	14	14	16	21	21	23	24	..	17	1-27-06	" " "	Contractor.
418	Slag Block	....	5	7	7	9	9	13	17	18	..	..	11	2-8-06	" " "	"
419	Montello Block	Red	14	18	18	21	23	26	29	30	33	..	24	2-27-06	" " "	Engineer.
420	" "	"	12	15	15	16	17	17	19	22	30	..	18	3-1-06	" " "	"
421	Mack "	Buff	16	17	19	19	19	19	20	24	24	..	20	3-3-06	" " "	Maker.
422	Metropolitan Block	Dark Red	14	14	15	16	17	18	18	19	19	..	17	3-5-06	" " "	Contractor.
423	Harris Paver's	" "	15	23	25	27	27	29	29	29	32	..	26	3-10-06	" " "	Engineer.
424	Montello Block	" "	13	14	15	15	16	17	20	30	30	..	19	3-12-06	" " "	Contractor.
425	R. B. & T. "	Red	19	19	22	22	24	24	25	26	27	..	23	3-12-06	" " "	"
426	Montello "	Dark Red	15	17	18	18	18	19	21	23	26	..	19	3-14-06	" " "	Engineer.
427	" "	" "	10	11	11	18	19	19	22	22	28	..	18	3-16-06	" " "	"
428	" "	" "	11	13	13	14	18	19	23	23	30	..	19	3-17-06	" " "	"
429	" "	" "	12	14	16	17	18	18	18	26	26	..	18	3-20-06	" " "	"
430	" "	" "	18	20	20	21	22	22	26	28	29	..	23	3-20-06	" " "	"
431	Salisbury "	" Buff	32	33	33	34	35	38	39	40	44	58	39	3-21-06	Salisbury Brick Co.	Maker.
432	Montello "	....	14	17	18	18	19	21	21	23	24	..	20	3-27-06	City Engr., Baltimore.	Engineer.
433	" "	....	13	16	17	17	17	18	20	25	26	..	19	3-30-06	" " "	"
434	" "	....	14	14	15	18	19	19	20	21	23	..	18	3-31-06	" " "	"
435	" "	....	16	17	18	18	18	19	20	20	23	..	19	4-2-06	" " "	"
436	" "	...	15	17	18	20	20	20	21	21	29	..	20	4-3-06	" " "	"
437	" "	....	17	17	18	19	24	23	28	29	34	..	24	4-4-06	" " "	"
438	" "	....	16	19	20	23	24	24	29	29	30	..	24	4-7-06	" " "	"
439	" "	....	16	19	21	21	22	24	24	26	26	..	22	4-9-06	" " "	"
440	" "	....	16	18	18	18	20	21	23	27	29	..	21	4-10-06	" " "	"
441	" "	....	13	15	15	16	17	18	19	21	22	..	17	4-11-06	" " "	"
442	" "	....	16	16	19	20	20	21	22	22	24	..	20	4-11-06	" " "	"
443	" "	...	15	17	20	20	21	21	22	22	26	..	20	4-16-06	" " "	"
444	Zanesville "	Burnt Red	18	19	21	22	24	37	43	×	×	..	26	4-16-06	" " "	Contractor.
445	Montello "	....	13	13	14	14	15	15	16	17	17	..	15	4-17-06	" " "	Engineer.
446	Metropolitan Block	....	14	15	15	15	16	16	17	17	17	..	16	4-18-06	" " "	Contractor.
447	" "	...	12	13	14	14	15	15	16	16	19	..	15	4-20-06	" " "	"
448	Harris Block	Dark Brown.	14	16	16	17	19	19	19	21	24	..	18	4-21-06	Comm. for Opening Sts.	"
449	Montello Block	....	13	15	15	16	17	20	20	20	23	..	18	4-24-06	City Engr., Baltimore.	Engineer.
450	" "	....	16	17	18	19	20	23	24	29	31	..	23	4-24-06	" " "	"
451	" "	....	16	17	19	20	22	22	22	23	27	..	21	4-30-06	" " "	"
452	" "	....	14	18	19	19	21	21	21	23	24	..	20	5-1-06	" " "	"
454	Maxwell "	....	17	20	24	25	28	29	31	31	34	..	26	5-3-06	" " "	"
455	" "	....	19	19	19	20	23	23	23	26	27	..	21	5-3-06	" " "	"
456	" "	...	22	23	25	28	32	34	34	35	41	..	31	5-4-06	" " "	"

TABLE SHOWING RESULTS OF TESTS OF PAVING BRICK OBTAINED AT THE LABORATORY OF THE HIGHWAY DIVISION OF THE MARYLAND GEOLOGICAL SURVEY DURING 1906 & 1907.—Continued.

457	Montello Block.............	....	15	20	20	20	21	23	23	23	25	..	21	5-5-06	City Engr., Baltimore.	Contractor.
458	" "	....	18	19	19	20	23	23	25	26	28	..	22	5-5-06	" " "	"
459	" "	....	11	14	17	17	20	20	22	24	32	..	20	5-5-06	" " "	"
460	" "	....	12	18	19	19	22	23	24	26	26	..	21	5-5-06	" " "	"
461	" "	....	13	13	14	16	17	23	24	25	31	..	19	5-5-06	" " "	"
462	Maxwell "	....	21	23	23	23	25	27	28	28	30	..	25	5-9-06	" " "	"
463	Montello "	...	16	18	19	22	22	22	22	23	24	..	21	5-11-06	" " "	"
464	Maxwell "	....	16	19	20	20	20	22	22	23	27	..	21	5-16-06	" " "	"
465	" "	....	17	21	23	22	23	24	24	25	26	..	23	5-16-06	" " "	"
466	Century "	....	16	18	20	25	25	26	29	31	..	..	24	5-21-06	Comm. for Opening Sts.	Comm. for Opening Sts.
467	Montello "	....	13	15	16	16	20	24	25	26	28	..	18	5-23-06	City Engr., Baltimore.	Engineer.
468	" "	....	17	17	19	19	22	24	25	25	27	..	21	5-24-06	" " "	"
469	" "	....	12	15	16	17	17	19	23	24	29	..	19	5-24-06	" " "	"
470	" "	....	10	12	15	19	19	22	23	23	23	..	19	5-24-06	" " "	"
471	Maxwell "	....	18	18	18	19	19	20	20	21	21	..	19	5-25-06	" " "	"
472	Montello "	....	11	12	13	15	15	19	19	22	23	..	16	5-29-06	" " "	"
473	" "	....	15	15	16	16	19	21	23	24	27	..	20	5-31-06	" " "	"
474	" "	....	17	17	17	18	18	18	21	22	26	..	19	6-4-06	" " "	"
475	Shawmut "	....	12	14	14	19	22	22	22	24	25	..	19	6-5-06	R. J. Padgett.	Contractor.
476	Mack "	....	15	16	17	18	19	19	22	22	27	..	19	6-5-06	" "	"
477	Montello "	....	17	18	19	20	23	23	25	31	33	..	23	6-5-06	City Engr., Baltimore.	Engineer.
478	Maxwell "	....	22	22	22	23	24	25	26	26	33	..	25	6-7-06	" " "	"
479	Montello "	....	13	14	16	17	18	18	18	23	26	..	18	6-9-06	" " "	"
480	Harris "	....	17	17	17	18	18	18	20	23	24	..	21	6-11-06	Road Engr., Balto. Co.	Contractor.
481	" "	....	21	21	21	22	22	23	25	26	27	..	23	6-11-06	" " " "	"
482	Maxwell "	....	18	21	23	23	25	26	26	26	31	..	24	6-12-06	Comm. for Opening Sts.	Comm. for Opening Sts.
483	" "	....	18	21	21	22	23	23	24	24	27	..	23	6-13 06	" " " "	" " " "
484	" "	....	18	21	21	23	24	27	27	27	31	..	24	6-13-06	" " " "	" " " "
485	Calder Brick & Coal Co.....	...	20	21	21	22	23	24	24	25	26	..	23	6-14-06	City Engr., Baltimore.	Hudson Cem't & Sup. Co.
486	Maxwell Block.............	....	15	18	23	23	24	29	29	29	32	..	25	6-16-06	" " "	Engineer.
487	Metropolitan Block.........	....	11	11	11	12	12	13	13	14	16	..	18	6-16-06	Comm. for Opening Sts.	Contractor.
488	Montello Block	....	15	19	19	19	22	26	27	28	31	..	24	6-19-06	City Engr., Baltimore.	Engineer.
489	" "	....	15	16	19	20	21	23	23	23	25	..	21	6-22-06	" " "	"
490	" "	....	16	18	18	21	22	23	23	24	24	..	21	6-22-06	" " "	"
491	Maxwell "	....	19	20	22	24	24	24	25	25	25	..	23	6-28-06	Comm. for Opening Sts.	Comm. for Opening Sts.
492	" "	....	19	22	23	24	26	29	31	33	34	..	27	6-28-06	" " " "	" " " "
493	Montello "	....	15	16	17	18	20	20	24	25	25	..	20	6-29-06	City Engr., Baltimore.	Engineer.
494	Calder Brick & Coal Co.....	....	22	23	23	24	24	24	24	25	30	..	24	6-29-06	" " "	"
495	Maxwell Block.............	....	21	24	24	25	26	26	27	28	32	..	26	7-3-06	" " "	"
496	" "	....	19	20	21	22	22	29	31	31	32	..	25	7-3-06	" " "	"
497	Montello "	....	19	19	21	22	22	26	26	31	32	..	24	7-3-06	" " "	"
498	" "	....	17	19	21	21	22	22	26	29	29	..	23	7-3-06	" " "	"
499	Mack "	....	17	18	20	22	24	26	26	28	33	..	25	7-6-06	Baltimore County.	Baltimore County.
500	Montello "	....	18	18	19	20	21	22	22	23	26	..	21	7-6-06	City Engr., Baltimore.	Engineer.
501	" "	....	20	20	22	22	24	25	29	29	31	..	25	7-9-06	" " "	"
502	" "	....	13	16	17	18	18	19	21	21	24	..	19	7-13-06	" " "	"
503	Century "	....	16	18	20	20	23	24	26	..	..	..	21	7-13-06	" " "	"
504	Mack "	....	19	21	21	22	26	27	30	31	33	..	26	7-14-06	Baltimore County.	Baltimore County.
505	" "	....	22	26	26	26	28	29	31	32	33	..	28	7-14-06	" "	" "
506	" "	....	25	28	29	29	30	30	32	32	36	..	30	7-14-06	" "	" "

TABLE SHOWING RESULTS OF TESTS OF PAVING BRICK OBTAINED AT THE LABORATORY OF THE HIGHWAY DIVISION OF THE MARYLAND GEOLOGICAL SURVEY DURING 1906 & 1907.—Continued.

Number.	Name.	Color.	Percentage Lost in Rattler 1800 Revolutions. Percentage Lost by Each Brick in a Test. No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	Average.	Date of Tests.	Made at the Request of	Samples Selected by
507	Montello Block	....	10	18	18	21	22	22	22	24	27	..	21	8-1-06	City Engr., Baltimore.	Engineer.
508	" "	....	16	17	18	18	21	21	21	21	22	..	21	8-6-06	" " "	"
509	" "	....	19	22	23	23	23	29	31	32	33	..	26	8-6-06	" " "	"
510	" "	....	15	16	17	18	18	18	19	22	22	..	18	8-7-06	" " "	"
511	" "	....	15	16	16	18	22	23	24	26	28	..	21	8-8-06	" " "	"
512	Mack "	....	18	22	23	24	24	25	25	27	28	..	24	8-9-06	Baltimore County.	Baltimore County.
513	" "	....	20	21	22	23	23	23	24	28	30	..	24	8-9-06	" "	" "
514	H. Slingluff	Wire cut Dark Red.	32	36	39	42	47	48	48	49	51	..	44	8-14-06	H. Slingluff.	Maker.
515	Thornton Block	....	19	21	22	22	23	23	24	24	26	..	23	8-14-06	Comm. for Opening Sts.	Comm. for Opening Sts.
516	Metropolitan Block	....	17	17	17	18	19	19	19	24	34	..	20	8-20-06	City Engr., Baltimore.	Engineer.
517	" "	....	18	13	14	16	16	17	18	20	20	..	16	8-20-06	" " "	"
518	Montello Block	....	15	16	17	18	20	23	24	26	31	.	21	9-14-06	" " "	"
519	Mack "	....	18	21	21	22	24	26	27	29	32	..	25	9-14-06	Baltimore County.	Baltimore County.
520	" "	....	14	21	26	27	27	29	29	30	..	..	26	9-14-06	" "	" "
521	Baltimore "	....	40	43	55	56	59	61	66	66	67	..	57	9-19-06	H. Slingluff.	H. Slingluff.
522	Shawmut "	....	21	24	26	27	27	29	31	39	42	..	30	9-21-06	City Engr., Baltimore.	Engineer.
523	Montello "	....	16	18	19	19	21	21	22	22	27	..	21	9-25-06	" " "	"
524	Mack "	Light Red...	18	20	23	24	25	25	26	26	27	..	24	9-25-06	Mayor of Salisbury.	Mayor of Salisbury.
525	" "	Md. Red....	15	17	17	23	23	25	25	25	28	..	22	9-25-06	" "	" "
526	" "	Dark Red....	23	26	26	27	27	27	28	29	32	..	27	9-25-06	" "	" "
527	Shawmut "	....	19	21	21	22	22	23	25	25	34	..	23	9-26-06	Comm. for Opening Sts.	Comm. for Opening Sts.
528	Grafton "	....	18	20	20	22	22	23	25	26	29	..	23	9-28-06	" " " "	Maker.
529	Montello "	....	14	15	16	16	16	18	21	29	30	..	19	9-28-06	City Engr., Baltimore.	Engineer.
530	Shawmut "	....	19	19	19	20	20	21	24	30	31	..	23	9-28-06	Comm. for Opening Sts.	Comm. for Opening Sts.
531	" "	....	19	19	20	24	27	29	29	30	32	..	25	9-28-06	" " " "	" " " "
532	R. B. & T. Brick	....	28	30	31	31	32	33	35	40	45	..	34	10-4-06	" " " "	" " " "
533	Johnsonburg Vit. Brick	Dark Red...	16	18	19	22	23	23	23	24	25	..	21	10-4-06	Maker.	Maker.
534	Calder Brick & Coal Co.	....	20	21	22	23	23	24	25	25	27	..	23	10-8-06	City Engr., Baltimore.	Hudson Cem't & Sup.Co.
535	Montello Block	....	14	17	17	17	18	18	18	19	24	..	18	10-11-06	" " "	"
536	" "	....	15	18	22	23	24	24	26	29	32	..	24	10-11-06	" " "	"
537	Johnsonburg Vit. Brick Co.	....	17	18	19	20	20	20	20	21	34	..	21	10-12-06	Johnsonburg Vit. B. Co.	Maker.
538	Calder Brick & Coal Co.	....	20	20	21	22	23	24	24	25	25	..	22	10-13-06	Comm. for Opening Sts	"
539	Montello Block	....	12	12	14	16	16	16	16	19	21	..	16	10-15-06	City Engr., Baltimore.	Engineer.
540	" "	....	15	17	18	18	18	19	19	23	26	..	19	10-15-06	" " "	"
541	" "	....	19	19	20	22	24	25	26	29	40	..	24	10-16-06	P. K. Compton.	"
542	" "	....	15	17	17	18	20	21	26	27	30	..	22	10-20-06	City Engr., Baltimore.	"
543	" "	....	11	15	17	18	18	19	26	30	39	..	19	10-22-06	" " "	"
544	" "	....	16	18	21	21	23	23	26	27	36	..	23	10-22-06	" " "	"
545	Guise "	....	15	20	31	33	39	41	43	66	69	..	40	10-23-06	Comm. for Opening Sts.	Maker.

TABLE SHOWING RESULTS OF TESTS OF PAVING BRICK OBTAINED AT THE LABORATORY OF THE HIGHWAY DIVISION OF THE MARYLAND GEOLOGICAL SURVEY DURING 1906 & 1907.—Continued.

546	20th Century Block	....	17	17	18	18	18	20	22	23	32	..	21	10-23-06	Comm. for Opening Sts.	Maker.
547	Montello Block	....	10	12	13	14	15	16	16	18	21	..	15	10-31-06	City Engr., Baltimore.	Engineer.
548	Grafton "	....	23	25	26	26	26	27	27	29	30	..	26	11-2-06	Comm. for Opening Sts.	Comm. for Opening Sts.
549	" "	....	16	18	19	21	21	22	22	24	26	..	21	11-2-06	" " " "	" " " "
550	Patton Paver	....	18	20	20	21	22	25	26	26	26	..	23	11-2-06	Maker.	R. S. Green.
551	Montello Block	....	17	17	17	19	20	20	21	24	27	..	20	11-13-06	City Engr., Baltimore.	Engineer.
552	Maxwell "	....	13	13	14	15	17	18	18	19	20	..	16	11-14-06	Maker.	Maker.
553	20th Century Block	....	17	17	18	21	21	31	33	37	42	..	26	11-20-06	Comm. for Opening Sts.	Comm. for Opening Sts.
554	Montello Block	....	18	18	18	19	19	19	21	25	33	..	21	11-20-06	City Engr., Baltimore.	Engineer.
555	" "	....	17	20	21	23	24	24	26	27	31	..	24	12-3-06	" " "	"
556	Kuskequa "	....	16	17	17	20	20	20	24	28	26	..	21	12-11-06	" " "	Maker.
557	James M. Porter Block	....	28	35	37	38	38	39	39	40	48	..	38	12-27-06	" " "	"
559	Mack Block	....	14	15	16	16	16	17	18	19	19	..	17	1-27-07	Maker.	"
560	" "	....	12	14	16	16	20	21	21	22	23	..	18	1-28-07	"	"
562	Windber Brick	....	22	22	25	27	27	28	29	31	32	..	27	2-15-07	W. P. Kelley Brick Co.	W. P. Kelley Brick Co.
563	Grafton, W. Va. Block	....	17	19	20	20	20	21	21	21	22	..	20	2-25-07	City Engr., Baltimore.	Maker.
564	Minerva Block	....	27	28	29	30	30	32	33	33	35	..	31	3-4-07	Comm. for Opening Sts.	"
565	Windber Brick	....	26	26	27	27	28	29	30	31	40	..	29	3-18-07	W. P. Kelley Brick Co.	W. P. Kelley Brick Co.
566	Maxwell Block	....	14	18	18	19	20	23	27	28	39	..	22	4-2-07	City Engr., Baltimore.	Engineer.
567	" "	....	12	16	17	17	19	20	20	24	31	..	19	4-3-07	" " "	"
568	Williams Grove Brick Co.	....	23	24	25	28	28	30	30	31	33	..	28	4-7-07	Maker.	Maker.
569	Maxwell Block	....	14	15	16	16	19	21	23	23	25	..	19	4-27-07	City Engr., Baltimore.	Engineer.
570	" "	....	14	15	16	18	18	18	21	21	30	..	19	4-30-07	" " "	"
571	Thornton "	....	19	19	20	21	23	23	24	25	26	..	22	5-1-07	Maker.	Maker.
572	" "	...	21	21	22	23	23	25	27	32	33	..	24	5-1-07	"	"
573	Maxwell "	....	18	18	18	24	25	25	25	29	33	..	24	5-6-07	City Engr., Baltimore.	Engineer.
574	" "	....	17	19	20	21	21	23	24	24	25	..	21	5-13-07	" " "	"
575	" "	...	18	18	19	21	21	23	26	32	33	..	23	5-13-07	" " "	"
576	Shawmut "	....	21	22	22	23	25	26	28	29	34	..	26	5-13-07	Road Engr., Balto. Co.	Road Engr., Balto. Co.
577	Maxwell "	...	19	19	21	23	23	23	24	28	31	..	24	5-14-07	City Engr., Baltimore.	Engineer.
578	" "	....	17	20	21	21	23	23	24	25	26	..	22	5-20-07	" " "	"
579	" "	....	17	28	29	29	×	×	×	×	×	..	28	5-23-07	" " "	"
580	" "	....	14	15	18	21	22	37	42	48	49	..	29	5-29-07	" " "	"
581	" "	....	16	17	18	19	20	22	23	26	31	..	21	6-6-07	" " "	"
583	Metropolitan Block	...	14	14	16	16	16	16	16	17	18	..	16	6-17-07	" " "	"
584	Johnsonburg "	....	20	20	20	21	23	24	25	25	27	..	23	6-17-07	Maker.	Maker.
585	Maxwell Block	....	15	17	19	22	23	26	29	34	35	..	24	6-18-07	City Engr., Baltimore.	Engineer.
587	Thornton "	....	17	18	18	19	20	20	22	25	26	..	21	6-29-07	Baltimore County.	Baltimore County.
588	Maxwell "	...	12	15	16	17	18	20	30	34	34	..	22	7-8-07	City Engr., Baltimore.	Engineer.
589	Thornton "	....	17	17	18	18	19	19	20	21	24	..	19	7-16-07	Baltimore County.	Contractor.
590	Maxwell "	....	20	21	22	23	23	25	25	26	31	..	24	8-7-07	City Engr., Baltimore.	Engineer.
591	" "	....	19	19	19	20	20	20	23	28	33	..	23	8-7-07	" " "	"
592	Calder Brick & Coal Co.	...	22	23	26	27	27	28	33	34	36	..	28	8-20-07	" " "	"
593	Maxwell Block	....	28	29	31	35	35	41	46	52	59	..	39	8-22-07	" " "	"
595	" "	....	19	20	21	22	22	22	23	25	30	..	23	9-1-07	" " "	"
596	Penn "	.	18	20	21	22	23	25	25	26	30	..	23	9-7-07	Comm. for Opening Sts.	Comm. for Opening Sts.
597	Maxwell "	....	21	21	26	26	27	29	30	31	36	..	27	9-9-07	City Engr., Baltimore.	Engineer.
598	Penn "	....	21	24	27	27	29	30	31	31	47	..	30	10-21-07	Comm. for Opening Sts.	Comm. for Opening Sts.
599	Thornton "	...	22	23	26	26	27	31	34	37	41	..	29	10-21-07	City Engr., Baltimore,	Engineer.
600	Baltimore "	....	27	28	30	31	36	38	39	44	56	..	36	12-3-07	Baltimore Vit. Clay Co.	Baltimore Vit. Clay Co.

× Crumbled to pieces.

TABLE OF ROAD EXPENDITURES—FISCAL YEARS 1905-1907.§

County.		Total amount spent on Roads and Bridges.	Amount spent for repairs on Bridges.	Amount spent for new Bridges.	Amount spent for permanent improvement of Roads.	Amount spent for repairs on Roads.	No. of Steam Rollers owned in county.	
							By county.	Private.
Allegany,	1905.	$59,819.26	*	*	$7,500.00	*	2	1
	1906.........	60,000.00 ‡	*	*	*	*	2	1
	1907.........	75,000.00 ‡	*	*	*	*	2	1
Anne Arundel,	1905.........	40,000.00 ‡	*	*	*	*	..	1
	1906.	40,000.00 ‡	*	*	*	*	..	1
	1907.........	40,000.00 ‡	*	*	*	*	..	1
Baltimore,	1905.........	234,275.81	$5,567.70	$27,537.57	105,889.17	$95,330.87	4	9
	1906.........	218,023.61	7,780.16	6,890.45	116,052.55	87,300.45	4	9
	1907...	288,708.25	9,462.94	6,236.25	153,833.36	119,175.70	6	11
Calvert,	1905.	4,518.00	*	*	*	4,518.00	..	..
	1906.........	4,534.00	*	129.00	150.00	4,255.00	..	..
	1907.........	4,534.00	*	404.00	*	4,130.00	..	..
Caroline,	1905.........	11,073.87	1.417.27	1,255.34	*	8,973.71	..	..
	1906.........	12,995.96	1,274.47	1,052.93	2,754.40	10,261.54	..	..
	1907....	12,926.42	1,236.61	750.60	3,994.26	10,750.03	..	2
Carroll,	1905.........	34,214.58	*	11,013.11	5,800.00	*	..	..
	1906.........	35,000.00 ‡	*	*	*	*	..	..
	1907.	35,000.00 ‡	*	*	*	*	..	..
Cecil,	1905..... ...	52,782.60	5,548 09	*	5,500.00	*	1	..
	1906.........	32,251.53	4,820.21	*	11,152.26	*	1	..
	1907.........	38,232.06	3,419.15	2,469.06	*	*	1	1

* Not reported. ‡ Estimated by this office. § Figures given are exclusive of any contributions from the state treasury.

TABLE OF ROAD EXPENDITURES—FISCAL YEARS 1905-1907.—*Continued.*

County.		Total amount spent on Roads and Bridges.	Amount spent for repairs on Bridges.	Amount spent for new Bridges.	Amount spent for permanent improvement of Roads.	Amount spent for repairs on Roads.	No. of Steam Rollers owned in county.	
							By county.	Private.
Charles,	1905.........	$13,852.78	*	*	*	*	..	..
	1906.........	13,755.62	*	*	*	*	..	..
	1907.........	18,616.83	*	*	*	*	..	..
Dorchester,	1905.........	18,976.30	*	*	*	*	..	..
	1906.........	19,000.00 ‡	*	*	*	*	..	..
	1907.........	20,000.00 ‡	*	*	*	*	..	..
Frederick,	1905.........	41,500.00	$5,000.00	$13,780.00	$7,000.00	$19,720.00	..	1
	1906.........	42,000.00 ‡	*	*	*	*	..	1
	1907.........	45,000 00 ‡	*	*	*	*	..	1
Garrett,	1905.........	16,290.21	1,500.00	*	*	14,790.21	..	..
	1906.........	19,650.89	6,000.00	*	*	13,650.89	..	..
	1907.........	21,099.89	7,000.00	*	*	14,099.89	..	..
Harford,	1905.........	82,633.33	*	*	48,885.17	*	2	..
	1906.........	33,889.15	*	*	12.408.05	*	8	..
	1907.........	25,111.11	*	*	14,848.09	*	8	..
Howard,	1905.........	22,455.57	*	*	*	*	..	..
	1906.........	25,000.00 ‡	*	*	*	*	..	1
	1907.........	25,000.00 ‡	*	*	*	*	..	1
Kent,	1905.........	20,505.46	3,504.32	2,240.22	*	14,760.92	..	..
	1906.........	30,259.10	5,157.10	2,440.00	*	22,662.00	..	..
	1907.........	29,172.89	5,785.31	1,815.78	*	21,571.85	..	..

* Not reported. ‡ Estimated by this office.

TABLE OF ROAD EXPENDITURES—FISCAL YEARS 1905-1907.—*Continued.*

County.		Total amount spent on Roads and Bridges.	Amount spent for repairs on Bridges.	Amount spent for new Bridges.	Amount spent for permanent improvement of Roads.	Amount spent for repairs on Roads.	No. of Steam Rollers owned in county.	
							By county.	Private.
Montgomery,	1905.........	$33,500.61	$2,169.95	$5,000.00	$11,145.03	$15,185.63	..	1
	1906.........	30.115.66	4,843.41	3,000.00	8,408.23	16,246.54	..	1
	1907.........	35,000.00 ‡	*	*	*	*	..	4
Prince George's,	1905.........	37,401.59	3,047.83	3,425.50	19,808.75	11,119.51	..	2
	1906.........	40,000.00 ‡	*	*	*	*	..	2
	1907.........	50,000.00 ‡	*	*	*	*	..	2
Queen Anne's,	1905.........	16,000.00 **	*	*	*	*	..	..
	1906.........	18,000.00 ‡	*	*	*	*	..	..
	1907.........	20,000.00 ‡	*	*	*	*	..	..
St. Mary's,	1905.........	6,009.15	*	*	*	6,009.15	..	..
	1906.........	5.068.00	68.00	*	*	5,000.00	..	..
	1907.........	5,000.00	*	*	*	5,000.00	..	..
Somerset,	1905.........	10,745.45	1,868.84	1.050.00	*	7,826.61	..	..
	1906.........	9,220.34	1,546.61	1,050.00	*	6,623.73	..	..
	1907.........	10,806.93	1,759.55	865.00	*	8,182.38	..	..
Talbot,	1905.........	14,000.00 ‡	*	*	*	*	..	..
	1906.........	15.000.00 ‡	*	*	*	*	..	..
	1907.........	15,000.00 ‡	*	*	*	*	..	..
Washington,	1905.........	25,479.12	3,781.07	2,180.95	10,000.00	9,517.00	..	1
	1906.........	27,000.00 ‡	*	*	*	*	..	1
	1907.........	30,000.00 ‡	*	*	*	*	..	1

* Not reported. ** Estimated by county officials. ‡ Estimated by this office.

TABLE OF ROAD EXPENDITURES—FISCAL YEARS 1905-1907.—*Continued.*

County.		Total amount spent on Roads and Bridges.	Amount spent for repairs on Bridges.	Amount spent for new Bridges.	Amount spent for permanent improvement of Roads.	Amount spent for repairs on Roads.	No. of Steam Rollers owned in county.	
							By county.	Private.
Wicomico,	1905........	$15,000.00 **	*	*	*	*	..	..
	1906.........	15,000.00 ‡	*	*	*	*	..	..
	1907.........	15,000.00 ‡	*	*	*	*	..	..
Worcester,	1905.........	12,000.00 **	*	*	*	*	..	..
	1906.........	20,000.00 ‡	*	*	*	*	..	..
	1907...... ...	35,000.00 ‡	*	*	*	*	2	..
State,	1905.........	772,488.19	....	....	....	...	9	15
	1906.........	765,263.86	....	..	....	....	10	17
	1907.........	894,207.33	....	....	....	....	12	25

* Not reported. ** Estimated by county officials. ‡ Estimated by this office.

PART II

MARYLAND MINERAL INDUSTRIES

1896-1907

BY

WM. BULLOCK CLARK AND EDWARD B. MATHEWS

MARYLAND MINERAL INDUSTRIES

1896-1907

BY

WM. BULLOCK CLARK AND EDWARD B. MATHEWS

INTRODUCTORY.

Maryland produces * a great variety of mineral products, many of which afford at the present time the basis of important commercial enterprises, while others give promise of future value. Still others occur in such small quantities as to raise doubts as to their ultimate economic importance. Most of those now employed can be still further developed with the prospect of an increased production in future years.

Many of the Maryland minerals have been worked since early colonial days, especially the brick clays and the iron carbonate ore. The Maryland coal deposits also were early discovered, and have been the basis of an important industry for more than half a century. Still other mineral products have been developed within quite recent years, the annual value of the Maryland mineral output being steadily on the increase.

The ancient crystalline rocks, confined for the most part to the Piedmont region between the Catoctin Mountain and the Chesapeake have afforded the most varied mineral substances. Here occur the most important building-stones; the granite of Port Deposit, Woodstock, Ellicott City, and Guilford; the gneiss of Baltimore City; the marble of Cockeysville and Texas; the slate of Cardiff; the crystalline limestone of Westminster; and the serpentine of Cardiff, Broad Creek, and Bare Hills. In these oldest rocks occur also the ores of gold, copper, chrome, lead, and zinc. Iron ore is also found here while all the flint, feldspar,

* The statistics of mineral production are collected each year by the Maryland Geological Survey in co-operation with the U. S. Geological Survey.

kaolin, talc, soapstone, asbestos, and mica in the State must be sought for in these rocks. These older rocks also appear in the Blue Ridge district underlying the Middletown Valley, where they have yielded traces of copper, antimony, and iron.

Rocks of later age, forming what geologists call the Paleozoic system, constitute the western section of the State. They furnish sandstone and limestone suitable for building purposes, the latter also being burned extensively for agricultural uses. There are also important deposits of cement rock that have afforded the basis for an extensive industry. At the top of this Paleozoic system of rock formations are the coal beds of the famous Cumberland-Georges Creek coal basin, including the "Big Vein" that is universally thought to furnish the highest quality of steam and smithing coal. These same rocks also contain important deposits of fire-clay and iron ore, the former affording the basis for a very important fire-brick industry.

The post-Paleozoic formations of the State, although not as rich in mineral products, are not devoid of deposits of economic value. The interesting variegated limestone breccia, known as Potomac marble, and the brown sandstone of Frederick and Montgomery counties belong to the oldest of these post-Paleozoic strata. The series of still unconsolidated beds representing much of the remainder of post-Paleozoic time and comprising all of Eastern and Southern Maryland, and known as the Coastal Plain, furnishes the chief supply of brick, potter's and tile clay; of sand, marl, and diatomaceous earth (silica); and much of the iron ore. The clay industry, particularly, is one of the most important in the State and is largely based on the clays of this region.

There has been a steady increase in the annual output of Maryland mineral products during the past twelve years, since the organization of the State Geological Survey. In that period the total has nearly doubled while the people directly and indirectly affected have greatly increased in number. The value of the production for each year is as follows:

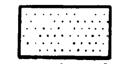
1896	1897	1898	1899	1900	1901
$5,834,498	$5,475,729	$5,944,150	$6,409,467	$6,939,543	$8,175,244

1902	1903	1904	1905	1906	1907
$9,282,339	$10,883,498	$9,515,093	$10,516,351	$10,915,472	$10,960,826

PLATE IX.

- **DEVONIAN.**
  - **Upper Devonian** .... **Catskill**
    - Alternating red shales and sandstones; 1900-2000 ft.
  - **Jennings**
    - (Genesee-Portage-Chemung.)
    - Vari-colored shales and sandstone; 3300-4800 ft.
  - **Middle Devon-** ... layers; 1200-2700 ft.
  - **Weverton**
    - White sandstone quartzite and conglomerate; 800-1200 ft.
  - **Loudon**
    - Dark slate with limestones, shales, sandstones and conglomerates; 100-800 ft.
    - **Setters quartzite and mica schist**
      - Micaceous quartz schist or vitreous quartzite usually carrying black tourmalines.
- **ARCHEAN..**
  - **ALGONKIAN** .... **ACID AND BASIC VOLCANICS**
    - Fine grained compact rocks usually much altered by development of sericite and epidote.
  - **Baltimore gneiss, etc.**
    - Highly crystalline gneiss of alternating hornblendic, micaceous and quartzose types, often intruded with pegmatites, granites, gabbros and serpentines.

PATTERNS.



The total annual output of mineral products had remained stationary for some years prior to 1896 and showed but little increase for the first year or two thereafter. In 1899 the total value exceeded six million dollars for the first time, but from that year onward increased steadily and rapidly until 1907, which shows the largest total annual value of mineral production of any year in the history of the State. The marked increase in values in 1903 was due to the anthracite coal strike of 1902, which brought about unusually high prices for all kinds of coal, the increase in this product alone being sufficient to account for the sudden increase in the total production. If conditions had been normal the output of Maryland mineral products would probably have been less than nine and one-half million dollars although showing a slight increase, however, over 1902. The years 1902, 1903, and 1904, show, therefore, with the exception cited, a gradual increase in mineral production over previous years. In 1905 and 1906 the increase again became rapid, due in part to the rebuilding of Baltimore, but in 1907 only a slight increase is shown, on account of the business depression prevailing during the latter half of that year. Under normal business conditions the total output for 1907 would have exceeded $11,000,000.

The following table shows the value of the various Maryland mineral products each year from 1896 to 1907:

VALUE OF THE ANNUAL OUTPUT OF MINERAL PRODUCTS, 1896-1907.

Year.	Coal.	Stone.	Flint and Feldspar.	Sand and Gravel.	Lime and Cement.
1896	$3,299,928	$457,764	*	*	$365,477
1897	3,363,996	458,811	*	*	286,441
1898	3,532,257	703,873	*	*	399,938
1899	3,667,056	636,547	*	*	372,322
1900	3,927,381	727,640	$33,420	*	421,745
1901	5,046,491	866,524	45,929	*	488,322
1902	5,579,869	1,113,854	83,236	*	487,597
1903	7,189,784	1,126,992	86,898	*	469,113
1904	5,729,085	1,160,676	98,867	$219,268	345,329
1905	5,831,760	1,409,053	75,552	436,828	393,741
1906	6,474,793	1,370,924	126,832	285,797	383,135
1907†	6,623,697	1,541,330	90,860	277,106	404,794

* Records incomplete.

† Provisional figures; a few small producers still delinquent.

VALUE OF THE ANNUAL OUTPUT OF MINERAL PRODUCTS, 1896-1907.—*Continued.*

Year.	Clay and Clay Products.	Ores (gold, copper, iron, mineral paint).	Mineral Waters.	Miscellaneous (soapstone, talc, marl, silica, etc.).	Total.
1896	$1,595,055	$53,304	$58,339	$4,631	$5,834,498
1897	1,312,889	27,660	21,185	4,747	5,475,729
1898	1,254,860	18,862	29,779	4,531	5,944,150
1899	1,683,596	26,557	13,045	10,344	6,409,467
1900	1,714,234	67,429	36,849	10,845	6,939,543
1901	1,613,663	45,135	57,680	11,500	8,175,244
1902	1,915,417	61,826	45,100	5,500	9,282,339
1903	1,921,821	33,612	45,918	9,360	10,883,498
1904	1,886,277	25,421	44,320	5,850	9,515,093
1905	2,282,856	35,152	44,627	6,782	10,516,351
1906	2,178,617	15,624	58,334	21,416	10,915,472
1907†	1,863,316	37,767	86,606	35,350	10,960,826

† Provisional figures; a few small producers still delinquent.

COAL.

The coal deposits of Maryland * are confined to western Allegany and Garrett counties and constitute a part of the great Appalachian coal field which covers portions of Pennsylvania, Maryland, Virginia, West Virginia, Ohio, Kentucky, Tennessee, and Alabama. Throughout the western portion of this field the rocks with their contained coal beds lie nearly horizontal, but to the eastward low folds that gradually increase in intensity are developed until the "canoe-shaped" basins of central Pennsylvania, western Maryland, and eastern West Virginia are reached. As a result of this increased folding eastward the coals have been metamorphosed through heat and pressure with a relative reduction in the amount of volatile carbon, the coals gradually changing from the soft bituminous to the semi-bituminous varieties with a further change to the hard anthracite still farther eastward in the anthracite field of Pennsylvania. In general the coal beds are thickest along the eastern margin of the field and thin westward. Many of the coal seams can be traced continuously over thousands of square miles, while others have only a local development.

The Maryland coals placed on the market belong to the group of semi-bituminous coals and possess great value for steam and smithing purposes. They are used extensively as fuel for locomotives, steamboats, and

* See Report on the Coals of Maryland, Md. Geol. Survey, Vol. V. Part 4, 1905, and Geological Maps of Allegany and Garrett Counties.

factories, finding a ready market in Baltimore, New York, and elsewhere along the Atlantic border.

The Maryland coals occur in five basins, known as the Georges Creek basin, the Upper Potomac basin, the Castleman basin, the Lower Youghiogheny basin, and the Upper Youghiogheny basin. The present production of coal for the market is almost exclusively confined to the first two basins. The far greater prominence of the Georges Creek basin has led to the application of the name "Georges Creek coal" to most of the coal shipped from the State. Until within recent years practically all of this coal came from the Pittsburg seam or "Big Vein," but the gradual exhaustion of this wonderful seam has led to the exploitation with most satisfactory results of many of the "Small Veins" both above and below the chief seam. There are many companies to-day mining the smaller seams either exclusively or in conjunction with the large seam. There is unquestionably a great future for these smaller seams in Maryland, especially in the Upper Potomac basin in southern Garrett County, where they reach their greatest thickness. The total amount of coal in these small seams exceeds many fold that originally contained in the "Big Vein."

The many coal seams in the Maryland Coal Measures are shown on the accompanying vertical section. The figures given represent the thickness of the seams from roof to floor, including the coal, bone, slate, etc., and the distances between important beds.

THE FOLLOWING ANALYSES SHOWS THE AVERAGE COMPOSITION OF THE LEADING MARYLAND COALS.

Coal Seams.	Moisture.	Volatile Carbon.	Fixed Carbon.	Ash.	Sulphur.	Calorimetric values in	
						Calories.	B. T. U.
Upper Sewickley or "Tyson"....	.83	20.22	70.09	8.86	1.40	7,784	14,011
Pittsburg or "Big Vein"	.70	18.78	73.13	7.12	1.02	7,920	14,256
Bakerstown or "Four-foot" ...	1.10	18.64	70.32	9.94	2.07	7,757	13,973
Upper Freeport or "Three-foot".	1.21	19.47	68.70	10.17	1.73	7,764	13,975
Lower Kittanning or "Six-foot"..	1.26	19.52	67.20	12.01	2.13	7,484	13,471
Brookville or "Bluebaugh" ..	.91	21.04	68.83	9.22	1.30	7,729	13,912

The most important of the seams, after the Pittsburg or "Big Vein," are the Upper Sewickley, the Bakerstown, the Upper Freeport, and the Middle and Lower Kittanning, all of which are being successfully mined at the present time. Others, like the Franklin or "Dirty Nine," contain so little good coal as to be practically valueless.

Although coal was discovered in the Georges Creek basin as early as 1782, the first eastern shipments from the Maryland coal district were not made until 1830, when small amounts were transported by barges down the Potomac River. The first company was incorporated in 1836. Since the construction of the Baltimore and Ohio Railroad in 1842 and of the Chesapeake and Ohio Canal in 1850, the output from the Maryland mines has increased very rapidly, and more than 30 companies are now engaged in the mining of coal.

The total annual value of the output of Maryland coal has doubled since 1896, in part due to an increased production and in part to an enhancement in the price. The following table shows the total quantity in long tons of coal mined and its value for each year from 1896 to 1907:

ANNUAL PRODUCTION OF MARYLAND COAL, 1896-1907.

	Loaded at mines for shipment.	Sold to local trade and employees.	Used at mines for steam and heat.	Total quantity mined.	Total value.	Average price per ton.	Average number of days active.	Average number of employees.
1896	3,632,239	47,363	19,939	3,699,541	$3,299,928	$.89	204	4,039
1897	3,921,163	24,787	20,235	3,966,185	3,363,996	.85	262	4,719
1898	4,124,098	32,983	16,922	4,174,003	3,532,257	.85	253	4,818
1899	4,211,233	61,384	19,701	4,292,318	3,667,056	.85	275	4,624
1900	3,526,374	46,040	21,057	3,593,471	3,927,381	1.09½	203	5,319
1901	4,503,563	36,859	24,870	4,565,292	5,046,491	1.10½	262	5,333
1902	4,631,585	43,421	31,967	4,706,973	5,579,869	1.18½	242	5,827
1903	4,243,496	47,341	36,096	4,326,933	7,189,784	1.66	219	5,859
1904	4,215,816	44,477	37,584	4,297,877	5,729,085	1.33	226	5,671
1905	4,474,104	44,446	42,646	4,561,196	5,881,760	1.28	252	5,948
1906	4,760,108	44,916	48,059	4,853,083	6,474,793	1.33½	250	6,438
1907	4,846,323	43,269	50,254	4,939,846	6,623,697	1.34	263	5,880

There was a gradual increase in the tonnage from 1896 to 1899 but 1900 saw a considerable decrease. In 1901, however, the amount mined exceeded that in any previous year and in 1902 there was a still further increase. In 1903 there was a decrease in tonnage over 1902, although the value was greater by $1,609,915 than in the preceding year, due to the higher price of coal. The production in 1904 remained about the

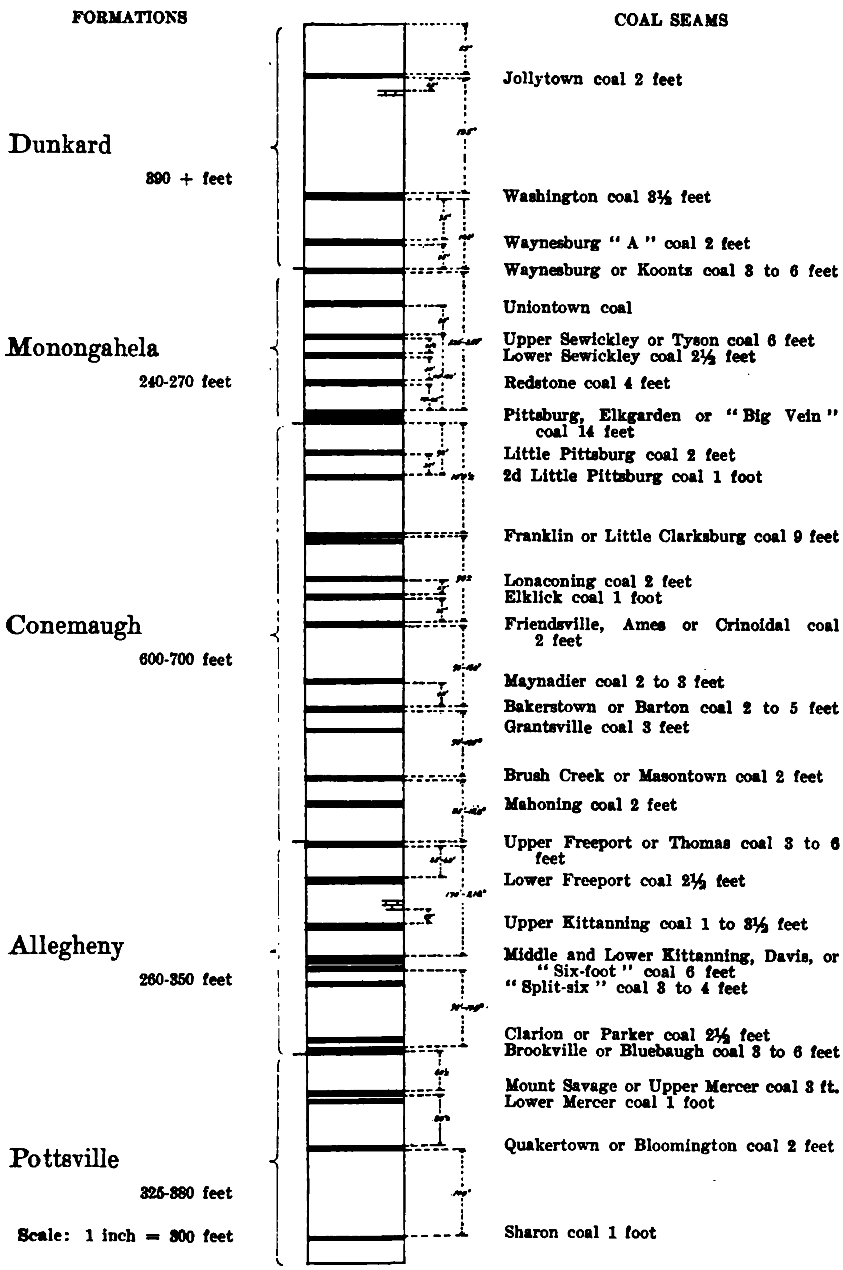


FIG. 1.—Columnar section showing relative positions of Maryland Coal seams.

same as in the preceding year, but the total value fell off greatly as compared with 1903, although not reaching the value for 1902. In 1905 there was some increase, both in tonnage and total value, and this was still more marked in 1906. In 1907 there was a still further increase, although less than the preceding year, on account of depressed business conditions in the late months of 1907.

The average price of coal for the 12-year period since 1896 has been \$1.15 per long ton. During the first half of this period it was \$0.94 and during the last half \$1.34 per long ton on the average. The price reached the highest figure in the history of the Maryland coal industry, \$1.66, in 1903, following the anthracite coal strike of the year before when the price of all varieties of coal rose greatly in value. Since 1903 the average price has been \$1.32. During 1904, 1906, and 1907 it was somewhat in excess of this but was slightly less in 1905, when it reached the lowest average price since 1902.

There is a difference in the average price obtained for the Big Vein and Small Vein coals and also between the Allegany and Garrett County coals from the same seams. Taking the year 1907 as an example, the average price for the Big Vein coal was \$1.45 per long ton while the Small Vein coals from Allegany County brought only \$1.18 per ton. At the same time the Small Vein coals in Garrett County brought only \$1.08 per ton. The difference in price seems hardly justified by the difference in the quality of the coals. More or less coal from the Small Veins is now mixed by many of the companies with the Big Vein coal without materially deteriorating its quality.

The average number of men employed in coal mining in Maryland increased from 4039 in 1896 to 6438 in 1906. The number was somewhat less in 1907, amounting to only 5880, according to the reports received, but the average number of days the mines were in operation increased from 250 to 263. In practically all the mines the working day is 10 hours long. In only a few of the smaller mines is there a 9-hour day.

The total tonnage of coal mined in Maryland to the close of 1907 is estimated at about 132,000,000 long tons which, at an average price of \$1 per ton, represents a total value of \$132,000,000.

LIST OF COAL OPERATORS.

ALLEGANY COUNTY.

OPERATOR.	OFFICE ADDRESS.	NAME OF MINE.	NEAREST PLACE.	COAL SEAM.
Consolidation Coal Company	Baltimore	Ocean No. 1	Ocean	Big Vein.
"	"	Ocean No. 3	Hoffman	"
"	"	Ocean No. 3½	Eckhart	"
"	"	Ocean No. 7	Lord	"
"	"	Ocean No. 8	Midland	"
"	"	Tyson No. 7	Lord	Tyson.
"	"	Tyson No. 8	Midland	"
"	"	Tyson No. 9	Frostburg	"
Union Mining Company	Mt. Savage	Union	"	Big Vein.
New York Mining Company	"	Union No. 1	Allegany	"
"	"	Union No. 2	"	"
Barton and Georges Creek Valley Coal Company	Baltimore	Carlos	Carlos	"
Potomac Coal Company	"	Potomac	Barton	Bakerstown.
Georges Creek Coal and Iron Company	"	No. 1	Lonaconing	Big Vein.
"	"	No. 12	"	"
"	"	No. 13	"	"
"	"	No. 14	"	"
"	"	No. 16	"	Tyson.
"	"	No. 17	"	"
American Coal Company	Lonaconing	Caledonia	Barton	Big Vein and Tyson.
"	"	Jackson	Pekin	Big Vein and Waynesburg.
Maryland Coal Company	New York	Appleton and Kingsland	Lonaconing	Big Vein.
"	"	New Detmold and Patton	"	"
New Central Coal Company	"	Koontz	Koontz	Big Vein and Tyson.
"	"	Big Vein	Lonaconing	Big Vein.
Piedmont and Georges Creek Coal Company	Frostburg	Washington No. 1	Eckhart	"
"	"	Washington No. 2	"	Big Vein and Tyson.
"	"	Washington No. 3	Franklin	Lower Kittanning.
"	"	Washington No. 4	"	"
"	"	Washington No. 5	"	Bakerstown.
Piedmont Mining Company	Baltimore	Pekin	Pekin	Big Vein.
Midland Mining Company	Cumberland	New Enterprise	Midland	"
"	"	Trimble	Mt. Savage	Lonaconing and Franklin.
Bowery Coal Company	Frostburg	Bowery	Midlothian	Big Vein.

LIST OF COAL OPERATORS.—Continued.

OPERATOR.	OFFICE ADDRESS.	NAME OF MINE.	NEAREST PLACE.	COAL SEAM.
H. and W. A. Hitchins Coal Company	Frostburg	Borden	Frostburg	Big Vein.
Phœnix and Georges Creek Mining Company	Philadelphia, Pa.	Phœnix	Phœnix	"
"	"	Elkhart	"	Bakerstown.
Braller Mining Company	Mt. Savage	Braller	Mt. Savage	Big Vein.
Moscow-Georges Creek Mining Company	Cumberland	Moscow No. 2	Moscow Mills	"
"	"	Moscow No. 3	"	Bakerstown.
Barton Mining Company	"	Moscow No. 1	Barton	"
Frostburg Fuel Company	Frostburg	Tyson No. 2	Frostburg	Tyson.
Chapman Coal Mining Company	Baltimore	Swanton	Barton	Bakerstown and Tyson.
Cumberland-Georges Creek Coal Company	Philadelphia, Pa.	Penn	Franklin	Bakerstown.
Frostburg Coal Mining Company	"	Morrison	Reynolds	Upper Freeport and Bakerstown.
Georges Creek Basin Coal Company	Cumberland	Short Gap	Eckhart	Upper Freeport.
Davis Coal and Coke Company	Baltimore	Buxton	Luke	Lower Kittanning.
Wachovia Coal Company	Cumberland	Waco	Clarysville	"
Cumberland Basin Coal Company	Pamosa	Parker	Pamosa	Parker.
"	"	Bond	"	Bluebaugh.
McMullen Brothers	Frostburg	Partridge Run	Barrelville	"
		GARRETT COUNTY.		
George C. Pattison	Bloomington	Pattison	Bloomington	Lower Kittanning.
Bloomington Coal Company	"	Bloomington	"	"
Monroe Coal Mining Company	Barnum, W. Va.	Elk Run No. 1	Barnum	"
"	"	Elk Run No. 3	"	Bakerstown.
Three Forks Coal Mining Company	Philadelphia, Pa.	Three Forks	Chaffee	Lower Kittanning.
Hamill Coal and Coke Company	Blaine, W. Va.	Hamill No. 1	Blaine	"
Potomac Valley Coal Company	"	Pee Wee or Darwin	"	Upper Freeport.
Blaine Mining Company	"	Blaine	Dill	Lower Kittanning.
Garrett County Coal and Mining Company	Dodson	Dodson No. 1	Dodson	"
"	"	Dill No. 1	"	"
Upper Potomac Coal Company	Philadelphia, Pa.	Upper Potomac	Hubbard	"
Stoyer Run Coal Mining Company	"	No. 1	Stoyer	"
"	"	No. 3	"	Upper Freeport.
Beechwood-Cumberland Coal Company	"	Beechwood	Deal	"
Nethkin Coal and Coke Company	Bayard, W. Va.	Bayard	Bayard	"
Penn-Garrett Coal Company	Friendsville	No. 1	Kendall	Lower Kittanning.
"	"	No. 2	"	"
"	"	No. 3	"	"
Kendall Lumber Company	Hutton	Preston	Hutton	Upper Freeport.

COKE PRODUCER.

OPERATOR.	OFFICE.	WORKS.
Maryland Steel Company	Sparrows Point	Sparrows Point.

CLAYS AND CLAY PRODUCTS.

The clays of Maryland * are widely distributed and occur at various geological horizons. They are found most extensively throughout the eastern and southern portions of the State, although some very important clays occur in the central and western counties. The clays of Maryland are suitable for many economic purposes, including the manufacture of common brick, fire-brick, enameled-brick, stove-brick, terra-cotta, sewer-pipe, tile, and pottery.

ANNUAL PRODUCTION OF MARYLAND CLAYS AND CLAY PRODUCTS, 1896-1907.

	Brick and tile including fire-brick, stove-brick, etc.	Pottery, including white, yellow, and earthenware.	Raw clay for misc. uses.	Total.
1896	$1,422,359	$167,696	$5,000	$1,595,055
1897	1,070,265	235,017	7,607	1,312,889
1898	949,907	305,518	1,435	1,254,860
1899	1,317,915	361,726	3,955	1,683,596
1900	1,275,239	436,617	2,378	1,714,234
1901	1,272,175	333,480	8,008	1,613,663
1902	1,380,062	525,300	10,055	1,915,417
1903	1,435,566	473,255	13,000	1,921,821
1904	1,469,126	402,931	14,220	1,886,277
1905	1,885,009	364,368	33,479	2,282,856
1906	1,763,040	373,499	42,078	2,178,617
1907	1,512,008	315,697	35,611	1,863,316

The total annual value of the output of Maryland clays and clay products has very materially increased since 1896. There had been very little change in the annual production for several years prior to 1896 and a slight decrease occurred in 1897 and 1898. In 1899, however, the total reached the largest amount in the history of the industry up to that time and from that date to 1906 has shown a marked annual increase with the exception of a slight loss in 1901 and 1904 which, however, was more than made up in the succeeding years. There was some decrease during the past year on account of the general business depression in the closing months of 1907 and the difficulty experienced by the operators in securing labor in the earlier part of the year.

* See Report on the Clays of Maryland, Md. Geol. Survey, Vol. IV, Part 3, 1902.

The extensive clay deposits of Maryland are but partially utilized at the present time but the prospects are that they will be much more extensively employed in future years.

COMMON AND FRONT BRICK CLAYS.

Clays suitable for the manufacture of common and front brick, particularly the former, are widely distributed throughout the State. Brick making began in southern Maryland in colonial days, scattered references to the industry being found in the earliest records. It is evident that practically all of the common brick employed for building purposes in colonial days was made at the local brick yards.

Maryland common brick is made from three types of deposits, viz., the Coastal Plain sedimentary clays, the residual clays of the Piedmont Plateau, and the shale deposits of the Appalachian Region.

Clays suitable for the manufacture of common brick are found everywhere throughout the Coastal Plain. The Columbia loams of Pleistocene age form a mantle over most of the surface of the district and on account of their grittiness and ferruginous character are excellently adapted to the manufacture of common brick and are widely used in the vicinity of Baltimore. They have sufficient iron to burn to a good red color, enough fine particles to insure proper plasticity, and enough grit to prevent excessive shrinkage in burning.

The only Tertiary clay of any great importance for brick making is the Marlboro clay at the base of the Nanjemoy formation. It is common through sections of Southern Maryland and is well suited to the manufacture both of pressed and common brick.

The Lower Cretaceous formations afford important brick clays, the Raritan, however, furnishing chiefly buff-burning clays, although red-burning ones occur. The clays from this formation are best developed in Anne Arundel County. The Patapsco formation which underlies the Raritan contains a large amount of highly variegated clays and extends in a broad belt across the State near the western margin of the Coastal Plain. The clays of the Patapsco formation are more plastic than the

Columbia clays and as a general rule occur in beds of much greater thickness. They are particularly well adapted to the manufacture of stiff-mud brick while the Columbia clays are rather too gritty for this purpose. Next to the Columbia clays they are the most important brick clays in the eastern section of the State. They are located for the most part near the head of tide along the leading railroad lines and therefore possess great commercial importance.

In the Jurassic, the Arundel formation affords large supplies of iron-ore clays which are well adapted to the making not only of common brick but also of pressed brick. They are moderately silicious, highly plastic, and have sufficient iron to burn to a good red color. At some localities the Arundel clays are comparatively free from iron so they burn buff instead of red and lend themselves well to the production of terra-cotta and roofing-tile.

The residual clays of the Piedmont region are derived from either gneisses, granites, limestones, or schists, as a general rule, and in almost every case are quite ferruginous so that they not only burn to a deep red product but may do so at a comparatively low temperature. Those which are derived from a basic igneous rock, such as gabbro or peridotite, usually have a very high plasticity and consequently show a high shrinkage in burning. Owing to their high plasticity, however, they generally permit of the admixture of considerable sand, although the manufacturer often has some difficulty in thoroughly incorporating the material with the clay. The residual clays are likely to be variable in their depths owing to the uneven surface of the underlying rock, and consequently they may vary anywhere from 3 or 4 to 25 or more feet in thickness.

The shales suitable for brick making are to be found either in the Devonian or Carboniferous, although up to the present time only the former have been used. With an increase in demand for bricks in the counties of the Appalachian Region the Carboniferous shales will no doubt spring into prominence and be opened at a number of points. Many of these shale deposits will also probably be found available for the manufacture of vitrified brick.

ANNUAL PRODUCTION OF COMMON AND FRONT BRICK, 1896-1907.

	Common Brick.			Front Brick.			
	Amt. in M.	Value.	Price per M.	Amt. in M.	Value.	Price per M.	Total value.
1896	144,519	$987,706	$6.83	4,572	$97,426	$21.35	$1,085,132
1897	116,841	702,957	6.02	5,316	92,344	17.37	795,301
1898	121,831	722,473	5.93	5,890	87,433	14.84	809,906
1899	111,479	682,247	6.12	14,335	157,918	11.02	840,165
1900	117,830	724,013	6.14	4,439	60,729	13.68	784,742
1901	113,457	676,708	5.96	5,772	76,792	13.30	753,500
1902	141,235	879,995	6.23	3,457	45,375	13.13	925,370
1903	147,663	976,669	6.62	2,728	40,479	14.84	1,017,148
1904	160,279	1,048,850	6.54	2,245	37,537	16.72	1,086,387
1905	210,446	1,423,663	6.76	1,426	24,118	16.91	1,447,781
1906	204,238	1,267,771	6.21	2,266	31,968	14.11	1,299,739
1907	185,848	1.031,024	6.19	1,447	18,355	12.68	1,049,379

The brick industry has had a very variable production during the past 12 years. The smallest output of common brick was in 1899, when the total was 111,479 M, the value of the product, however, being greater than in 1901, when the price per M was less. The largest production was in 1905, immediately following the Baltimore fire, when it reached 210,446 M. The price was also high during the latter year, the total value of the production being far in excess of any previous year in the history of the brick industry.

The production of front brick has varied greatly from year to year and is less at the present time than it was some years ago. The production of front brick was very much greater in 1899 than during any other year in the front-brick industry, so that the total production of common and front brick during 1899 considerably exceeded the output for the year 1901, when there were much fewer front brick produced than in 1899.

The prices of both common and front brick have varied from year to year, although the price of common brick has been throughout most of the period between $6 and $7 per M. The front brick also during recent years has not varied as much as it did earlier and has been declining somewhat in price during the last three years, being $16.91 per M in 1905 and $12.68 in 1907.

The manufacture of brick, tile, and other clay products is grouped in

centers of which the most important are Baltimore, Allegany, Frederick, Washington, and Wicomico counties. The operations around Baltimore include most of the production of Baltimore and Anne Arundel counties which, with that of Baltimore City, constitute about 60% of the total for the State. The demands of Washington are satisfied in large part from brick yards in Alexandria County, Va., the Maryland production in areas adjoining the District being slight.

The industry of Allegany County is chiefly in fire-brick, refractory ware, and enameled-brick. The production from this region constitutes nearly 30% of the total for the State. The remaining 10% comes chiefly from Frederick, Hagerstown, Williamsport, and Salisbury, with smaller producers in nearly every county of the State.

TERRA-COTTA CLAYS.

The terra-cotta industry of Maryland has been comparatively little developed, although what has been done is sufficient to show that suitable materials for the purpose are not lacking within the limits of the State. The kinds of materials which have been chiefly employed for this purpose are the buff-burning Arundel clays, the sandy Patuxent clays, and the variegated Patuxent clays. All of these clays are well developed to the south of Baltimore, especially in Anne Arundel and Prince George's counties. At times the variegated Patapsco clay is also well adapted for terra-cotta work, particularly in the southern part of Baltimore City.

The production of terra-cotta has varied greatly from year to year. At times there has been little or no output while at other times the production has exceeded $100,000 in value for the year. Terra-cotta production has been confined to two or three works and only one concern was engaged in the industry during the past year.

SEWER-PIPE CLAYS.

The only sewer-pipe clays employed at the present time come from the Arundel formation, although it is probable that equally good clays could be obtained from the Pleistocene deposits and from the Patapsco formation. The small importance of the sewer-pipe industry in Maryland at

the present time is due rather to trade conditions than to lack of clays, for both the Arundel and Patapsco formations yield materials of considerable plasticity.

Sewer-pipe production is very small and has rarely amounted to more than a few hundred dollars annually.

ROOFING-TILE CLAYS.

The roofing-tile clays used in Maryland come from the Arundel and Patapsco formations. They show considerable variation. A roofing-tile clay must have good plasticity, good tensile strength, and must dry and burn without extreme shrinkage or warpage. It should also burn to a dense body. Such clays have been employed in the vicinity of Baltimore and a much larger industry could unquestionably be developed should there be a demand for the material.

The annual production of roofing tile has been very variable, during some years amounting to only a few thousand dollars while at other times it has exceeded $25,000 in value. The quantity burned depends upon the condition of the building trade and the demand for roofs of this character.

FIRE CLAYS.

The refractory clays found in Maryland are obtained either from the Coastal Plain formations or from the Carboniferous deposits of the Appalachian Region. The Carboniferous fire clays of Maryland have long been well known, the deposits having been discovered in 1837. The Pottsville formation is the chief source of the clays which are worked at the present time, mainly along the eastern flank of Savage Mountain. These Carboniferous fire clays occur in two forms, known as the plastic clay or shale, and the flint clay, both of which are highly refractory in character. After being ground and mixed they are made into fire-brick and other shapes.

In the Coastal Plain region fire clays are obtained from the Patapsco, Raritan, and Patuxent formations as well as in some instances from the decayed crystalline rocks beneath. The first three of these formations

contain lenses or extensive beds of white to yellow-white clays which frequently show a high resistance to fire and can be heated up to the fusing point of cone 27 without in many cases becoming vitrified.

The refractory-ware industry of Maryland is one of the most important branches of the clay-working industry found in the State. Among the more important products are fire-brick, enameled-brick, retorts, stove-brick, and stove-linings. The fire-brick are made both in western Allegany County and in Baltimore. The manufacture of enameled-brick is confined, however, to the former locality. Retorts are made in Baltimore, while stove-brick and stove-linings are largely manufactured in Cecil County.

ANNUAL PRODUCTION OF FIRE CLAY PRODUCTS, 1905-1907.

	Fire-Brick.					
	Amt. in M.	Value.	Price per M.	Stove-Linings.	Miscellaneous.	Total.
1905	14,042	$224,667	$16.00	$32,890	$67,771	$325,328
1906	14,278	266,980	18.70	32,200	80,430	379,610
1907	10,981	238,601	21.73	24,548	79,560	342,709

The production of fire-clay products is large. It has not shown any great change during the past few years, although larger in 1906 than in 1905 and 1907. The price of fire-brick per M has increased in recent years, being $21.73 on the average in 1907 as against $16 in 1905. The industry is limited to three centers, Allegany County, Baltimore City, and Cecil County.

POTTERY CLAYS.

The pottery clays include materials showing a wide range of composition. The clays suitable for the manufacture of stoneware are to be found at many points in the Patapsco formation, especially in Cecil County. At the base of the Patapsco formation in the same county there is often a bed of bluish-gray, very plastic stoneware clay. Aside from these Cecil County stoneware clays the most important are those outcropping along the shore of the Chesapeake from Bodkin Point southward.

Clays suitable for the manufacture of yellow-ware are to be found at

a number of points in the Arundel formation and also in the Columbia group, both being extensively drawn upon by the yellow and Rockingham ware manufacturers of Baltimore.

Clays for the manufacture of the common red earthenware are abundant and are obtained from the Columbia group and the Arundel, and Patapsco formations of the Coastal Plain, from the residual clays of the Piedmont Plateau northeast of Catonsville, and also from the residual clays of the Appalachian Region around Hagerstown. The Potomac clays near Baltimore also afford the basis for the manufacture of the higher grades of pottery.

ANNUAL PRODUCTION OF POTTERY, 1896-1907.

WHITE, CREAM COLORED, YELLOW, AND EARTHENWARE.

1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
$167,696	$235,017	$303,518	$361,726	$436,617	$333,480	$525,300	$478,255	$402,981	$364,368	$373,499	$315,697

The production of pottery was largest in 1902, when it exceeded a half-million dollars in value. Since that time the annual output has had a somewhat less value, the annual production for the past year being less than at any time during the last 10 years. The industry is, however, of importance, the various producers showing considerable variation in the amount of their output from year to year.

KAOLIN.

The kaolin, which is generally a residual white clay derived from feldspathic gneisses comparatively free from minerals containing iron, is best developed in Cecil County. The deposits of this region are closely related to those of adjoining portions of Delaware, although in the latter State part of the kaolin is derived from the decomposed pegmatites. The crude kaolin is washed and deposited in settling tanks, the greater part of the fine quartz and staining constituents being removed, and is subsequently dried under pressure. The Maryland material is used for fire clay and sagger clay but chiefly in the manufacture of paper.

The production of kaolin has been very small in recent years, the larger works not being continuously in active operation. The production the past year was somewhat larger than it has been in earlier years.

LIST OF CLAY OPERATORS.

BRICK AND TILE.

OPERATOR.	OFFICE.	WORKS.
Baltimore Brick Co	Baltimore	Baltimore City and County.
Baltimore Retort & Fire Brick Co	"	Baltimore.
Baltimore Vitrified Clay Co	"	"
Edwin Bennett's Roofing Tile Works	"	"
Chesapeake Brick Co	Brooklyn	Curtis Bay.
German Arch Stone Brick Co	Baltimore	"
Columbia Stove Brick Works	"	Baltimore.
Baltimore Terra Cotta Works	"	"
Frederick Stamp	"	"
Tri-Color Brick Co	Passaic, N. J.	
Berlin Brick Co	Berlin	Berlin.
Potee Brick Co	Baltimore	Brooklyn.
C. F. Thomas & Son Brick Co	Buckeystown	Buckeystown.
James C. Leonard	Cambridge	Cambridge.
Eastern Brick Co	Baltimore	Canton.
H. S. & V. M. Barnett	Chestertown	Chestertown.
George M. Collins	Crisfield	Crisfield.
Queen City Brick & Tile Co	Cumberland	Cumberland.
Cumberland Granite Brick Co	"	"
Burns & Russell Co	Baltimore	Dundalk.
The Maryland Terra Cotta Co	"	"
Jos. H. White & Son	Easton	Easton.
John Gilpin Brick Co	Elkton	Elkton.
Gardner Bros.	Cumberland	Ellerslie.
George P. Stouter, Executor	Emmitsburg	Emmitsburg.
Peter Brookey	Frederick	Frederick.
Frederick Brick Works	"	"
Maryland Brick & Supply Co	"	"
Savage Mountain Fire Brick Co	Frostburg	Frostburg.
Bilbrough & Bros	Greensboro	Greensboro.
D. N. & C. E. Henson	Hagerstown	Hagerstown.
James E. S. Pryor	"	"
L. H. Wiebel	"	"
Excelsior Brick & Pottery Co. of Baltimore	Halethorpe	Halethorpe.
Hancock Shale Brick Co	Hancock	Hancock.
F. F. Greenwell	Leonardtown	Hanover Mills.
Highland Brick Co	Highland	Highland.
Ferdinand Cook	Federalsburg	Hynson.
Elias W. Oursler	Westminster	Mt. Airy.
Andrew Ramsay	Mt. Savage	Mt. Savage.
Union Mining Co. of Allegany Co	"	"
Big Savage Fire Brick Co	Frostburg	Allegany.
Thompson-Starrett Co.	Washington, D. C.	Muirkirk.
Green Hill Fire Brick Co	North East	North East.
North East Fire Brick Co	"	"
United Fire Brick Co	"	"
Independent Brick Co	Orangeville	Orangeville.
Hugh McMichael	Pocomoke City	Pocomoke City.
David S. Strayer & Sons	Ridgley	Ridgley.
Champion Brick Co	Baltimore	Rosedale.
Clifton Hope	St. Michaels	St. Michaels.
Peninsula Brick Co	Salisbury	Salisbury.
Salisbury Brick Co	"	"

OPERATOR.	OFFICE.	WORKS.
W. S. Lewis & Son	Snow Hill	Snow Hill.
D. W. Zentz	Thurmont	Thurmont.
Robert E. Frizzell	Westminster	Westminster.
Cambria Brick Co	Whiteford	Whiteford.
Wicomico Brick Co	Salisbury	White Haven.
Conococheague Brick & Earthenware Co.	Williamsport	Williamsport.
Laurel Brick Works	Laurel	Laurel.

POTTERY.

OPERATOR.	OFFICE.	WORKS.
Edwin Bennett Pottery Co	Baltimore	Baltimore.
Edwin Bennett's Roofing Tile Works	"	"
Chesapeake Pottery	"	"
Columbia Stove Brick Works	"	"
M. Perine & Sons	"	"
Baltimore Clay Tobacco Pipe Works	"	"
George S. Kalb & Sons	Catonsville	Catonsville.
J. J. Nottnagel & Son	Frederick	Frederick.
Excelsior Brick & Pottery Co	Halethorpe	Halethorpe.

RAW CLAY.

OPERATOR.	OFFICE.	WORKS.
Big Savage Fire Brick Co	Frostburg	Allegany.
S. C. Chew	Mantua, N. J.	Bacon Hill.
Ernest Hartung	Baltimore	Baltimore.
J. C. Weaver's Sons	"	"
H. W. Frederick	Charlestown	Charlestown.
A. Hopkins	Dorsey	Dorsey.
Chas. W. Simpers	North East	Eder and Leslie.
W. R. Grosh, Estate of	Elkton	Elkton.
Josephus Smith	Hanover	Hanover.
Union Mining Co. of Allegany Co	Mt. Savage	Mt. Savage.
American Clay Co	Philadelphia, Pa.	North East.
Hanna Mining Co	North East	"
North East Fire Brick Co	"	"

STONE.

The rocks of Maryland * include many varieties of excellent building and decorative stones. The greatest amount of the product is obtained from that portion of the State north of Washington and east of Harper's Ferry, West Virginia. The central location of this area, traversed by two main railroad lines and several local ones, places it within convenient distance of the prominent cities and towns of the Middle Atlantic coast and renders the products both valuable and available wherever the local conditions are otherwise favorable. Counteracting the value of

* See The Building and Decorative Stones of Maryland, Md. Geol. Survey, Vol. II, Part 2, 1898, and Maryland Geology in Relation to Highway Construction, Md. Geol. Survey, Vol. III, Part 2, pp. 80-106.

this central location, however, is the fact that the State of Maryland includes but a section across a series of geological formations, which are present in Pennsylvania and Virginia, where there are offered similar opportunities for the quarrying of stone. In some instances operations were commenced in these areas earlier than in Maryland, with the result that trade has been diverted to neighboring States which might be gained for Maryland by more energetic and intelligent action on the part of the local operators. At the present time the operations in the area are in no wise commensurate with the supply of material at hand.

VALUE OF THE ANNUAL PRODUCTION OF STONE, 1896-1907.

	Granite value.	Sandstone value.	Slate value.	Marble value.	Limestone value.	Total.
1896	$251,108	$10,713	$72,142	$110,000	$13,801	$457,764
1897	247,948	10,000	53,939	130,000	16,924	458,811
1898	317,258	13,640	82,240	120,525	170,204	703,873
1899	423,823	24,426	93,595	77,000	17,703	636,547
1900	486,822	6,655	128,673	70,000	35,490	727,640
1901	613,356	4,546	105,798	68,100	74,724	866,524
1902	758,203	15,405	118,084	95,549	126,613	1,113,854
1903	837,787	2,170	137,631	83,672	65,732	1,126,992
1904	815,471	8,998	133,972	73,814	128,421	1,160,676
1905	957,048	12,984	151,215	138,404	149,402	1,409,053
1906	883,881	9,533	130,969	176,495	170,046	1,370,924
1907	1,169,942	13,859	116,060	98,917	142,552	1,529,580

The industry arising from the quarrying of stone is the third in importance among those based upon the mineral wealth of the State, being surpassed only by the coal and clay products. The statistics presented in the accompanying table giving the value of the stone produced annually from 1896 to 1907 show that the industry is well established and that it has shown a well-sustained growth during the last decade in spite of the less favorable conditions of the last two years. The figures suggest the beginning of an appreciable increase in the industry. This is due to the abnormally higher output demanded by the rebuilding subsequent to the Baltimore fire and to the increasing use of crushed stone in concrete and road construction. During the next few years this increase may be sustained by the demands arising from the construction of the filtration beds of the Baltimore sewerage system.

The largest industry in stone is that of quarrying granite and its associated rocks. This trade for the first time passed the million-dollar point in 1907. Under this title of "granite" are included such other crystalline rocks as gneiss, gabbro, and diabase. The growth in the production of granite has been healthy and bids fair to continue. Following that of granite is the quarrying and manufacture of slate. This is not only the most locally confined of the quarrying industries but is also one of the oldest, its origin dating back to the latter part of the eighteenth century. The output during the year of 1907 has been somewhat curtailed by serious cave-ins and the efforts of the operators to maintain and raise the selling price. In this they appear to have been more or less successful. The marble output which was appreciably increased in 1905 and 1906 has returned to its normal value. The limestone production varies widely from year to year, being conditioned in large part on the improvement work undertaken by the railroads, while the production of sandstone, which is relatively unimportant in Maryland, has just about held its own through the period represented in the table.

GRANITE.

The granites of the State are usually light-colored, granular aggregates of the minerals quartz, feldspar and mica, and may usually be distinguished from the gneisses in which the same minerals are arranged in various ways in a more or less banded manner. The granites best known beyond the limits of the State are those quarried at Port Deposit in Cecil County and at Granite (Woodstock) in Baltimore County. The facilities for quarrying and transportation are particularly good at the former locality. The quarries are beside the railroad tracks at the head of navigation on the Susquehanna and the quarry face extends from the level of the river to the top of the gorge wall, thus permitting the working of several benches with a minimum amount of stripping. The quarries are well equipped with machinery and maintain a large crushing plant.

The quarries at Granite are somewhat less favorably situated on a spur from the main line of the Baltimore and Ohio Railroad. The excavations of the different firms vary widely in extent but all are relatively shallow and for the most part beneath the general level of the surrounding country. The facilities for handling the product are sufficient for the demands and the product compares favorably with the best granites of the country.

Similar quarries of granite are situated at Guilford and Ellicott City in Howard County and at Frenchtown in Cecil County. Many other deposits of granite of considerable extent are known. These have only been worked to satisfy the local demands but offer opportunities for more extensive development. Fully two-thirds of the granite output from Maryland localities is used for building and monumental purposes, being furnished to the trade in both the rough and dressed state.

The gneisses, which are most extensively quarried in the vicinity of Baltimore, are used chiefly for backing, rubble, curbing, and as crushed stone for concrete and road-metal. The quarry face usually shows a series of roughly parallel bands which differ in texture and mineralogical composition. The even-grained light-colored silicious bands composed of quartz-feldspar aggregates with a little disseminated mica are the most valuable as they readily yield strong stones with roughly parallel sides suitable for curbing, paving-blocks, or foundation stone. The darker hornblendic and micaceous bands are of little value for structural purposes but may be used for rubble, backing, and crushed stone.

Under the general head of granite are included such crystalline rocks as gabbro ("niggerhead") and diabase, which are being extensively crushed for road-metal and concrete. The lighter colored varieties are occasionally used for structural work but their sombre tones and their hardness make them less desirable for such purposes than for road-construction to which they are especially adapted.

The subjoined table gives the value and chief uses of the granite, gneiss, and trap quarried in Maryland during the years 1896-1907.

VALUE OF THE ANNUAL PRODUCTION OF GRANITE, GNEISS, AND TRAP, 1896-1907.

	Sold in rough.		Dressed.		Paving Blocks.	Curbing.	Flagging.
	Building.	Monumental.	Building.	Monumental.			
1896	*	*	*	*	$33,933	*	*
1897	$146,213		$52,048	$2,700	3,828	.....	.....
1898	87,760		65,602	10,500	33,341	$27,747	
1899	104,167		137,377	21,518	24,075	$27,500	.....
1900	127,608		164,181	13,400	71,855	24,520	.....
1901	$181,608	$20,180	188,568	7,800	51,637	42,045	
1902	139,856	15,825	323,239	17,500	30,521	35,955	$7,301
1903	228,896	29,996	271,929	10,634	38,104	21,174	3,922
1904	124,994	15,037	270,971	8,139	46,864	14,870	19,001
1905	233,716	38,860	125,177	4,600	38,900	21,742	7,419
1906	211,524	80,780	113,693	1,730	51,539	27,745	3,788
1907	106,694	13,657	55,781	8,928	47,385	23,279	4,406

	Crushed stone.			Rubble.	Rip-rap.	Misc.	Total.
	Road.	Railroad.	Concrete.				
1896	*	*	*	*	*	*	$251,108
1897		$41,999		*	*	$1,660	247,948
1898		83,888		.....	$8,420	.....	317,258
1899		106,636		.....	2,550	.....	423,823
1900		84,151		.....	1,107	.....	486,822
1901	$37,962	13,092	$50,404	$18,560		1,500	613,356
1902	74,522	25,535	54,704	$9,055	2,250	20,940	758,203
1903	60,664	37,771	122,120	8,278	1,029	3,200	837,787
1904	128,672	5,537	137,102	31,155	3,881	9,328	815,471
1905	133,599	8,046	212,592	102,733	2,996	26,668	957,048
1906	125,655	5,803	171,869	52,563	4,290	32,902	883,881
1907	280,742	29,717	492,846	87,901	7,266	11,340	1,169,942

* Statistics incomplete in detail.

The figures of the accompanying table show that during the time represented the granite production has been about equally divided between building and monumental stock, crushed stone, and stone for miscellaneous purposes, such as paving, curbing, flagging, rubble, and rip-rap. During most of the period the production of higher grade stock has shown a normal growth, reaching the maximum in 1904. The most marked feature is the great increase in production of crushed stone resulting from the demands incident to the rapidly-increasing use of concrete and to the macadamizing of the roads of the State. The production of stone for concrete shows an abnormal increase in 1907 on account of the vast quantities used in the construction of the great dam at McCalls Ferry, Pa., for which all of the stone is quarried and crushed

at the company's plant near Bald Friar, Maryland. The value of this production would have been still further enhanced if it had been estimated at the usual market values. Since none of it is sold it has been valued only at the cost of production. Since the demands for this particular work will cease on the completion of the works there is likely to be a decrease in the next year or two unless it is offset by the expected increase in demands incident to the inauguration of state highways and the construction of the filtration beds for the Baltimore sewerage system.

The prices obtained vary widely according to the form of the product, the unit of measurement, the location of the quarries, and the character of the stone. The principal units employed are the cubic yard, perch, and ton for rough and crushed stone, the linear foot for curbing and the square foot for flagging. The relations between such units as yard, perch, and ton also vary from place to place, though the ton is generally the short ton of 2000 pounds, and the perch of 25 cubic feet, and the cubic yard weighing from 2500 to 2800 pounds according to the stone involved.

Rough building stone sold for about \$1.50 per ton; crushed stone for road-metal and concrete for from 60 to 90 cents per yard and perch and \$1 to \$1.50 per ton. Paving blocks sold for \$50 to \$60 per thousand. The prices given are in all cases f. o. b. at quarries or shipping point.

LIST OF GRANITE OPERATORS.

OPERATOR.	OFFICE.	QUARRY.
The Advance Quarry Co	Baltimore	Baltimore.
J. H. Atkinson	"	"
Harry C. Campbell	Windsor Hills	Windsor Hills.
Independent Quarry Co	Baltimore	Harford Road.
Wm. M. Longley Quarry Co	"	Franklin Road.
Daniel A. Leonard	"	Baltimore.
Maryland Quarry Co	"	Franklin Road.
The I. H. Peddicord & Sons Quarry and Transfer Co.	"	Gwynns Falls.
Wm. T. McKennar & Co	"	Baltimore.
The Schwind Quarry Co	"	"
The Hook & Ford Contracting Co	"	Woodberry and Dickeyville.
Standard Lime & Stone Company	"	Boonsboro and Dickerson.
Patapsco Quarry Co	"	Ellicott City.
Werner Bros.	Ellicott City	"
Lukens & Yerkes	Philadelphia	Frenchtown.

OPERATOR.	OFFICE.	QUARRY.
Chas. E. Ehmann	Baltimore	Govanstown.
Feaney & Atherton	Granite	Granite.
Guilford & Waltersville Granite Co	Baltimore	"
Miller & Kirkpatrick	Guilford	Guilford.
The Perryville Granite Co	Easton, Pa.	Perryville.
McClenahan Granite Co	Port Deposit	Port Deposit.
J. E. Baker	York, Pa.	Phœnix.
Thos. B. Gatch & Sons	Raspburg	Raspburg.
Frank H. Zouck	Reisterstown	Reisterstown.
John F. Parks	Timonium	Ruxton.
Thos. S. Gerry	Rowlandsville	Rowlandsville.
Armstrong & McDowell	Port Deposit	"
B. F. Pope Stone Company	Baltimore	Savage.
Frank Peach & Co	Woodstock	Woodstock.
Potomac Granite Co	Washington, D. C.	Montgomery Co.
W. T. Manning	Baltimore	near Savage.
Conway Quarry Company	"	Lochraven.
Thomas R. Martin & Sons	Woodlawn	Franklintown.

MARBLE.

Marbles are found in Harford, Baltimore, Carroll, Howard, Frederick, and Washington counties. They may be roughly divided into five classes: the clear white saccharoidal marbles of Baltimore County, the variegated fine-grained crystalline limestones and marbles of Carroll and Frederick counties, and the decorative marbles found along the western slopes of the Blue Ridge in Washington County, the Potomac marbles of the Frederick valley, the Verde Antique of Baltimore and Harford counties.

The Baltimore County marbles are quarried extensively along the Northern Central Railway about 15 miles north of Baltimore at Cockeysville and Texas. The quality of the rock at these two points varies widely. The rock at Texas is a coarse-grained marble of nearly pure lime carbonate with occasional fine-grained beds of denser color and richer in magnesium. It is not well suited to structural work and is quarried chiefly for burning into agricultural lime or for use as a flux. The rock at Cockeysville, on the other hand is a fine-grained dolomitic marble rich in magnesium, well adapted to building and decorative purposes. The individual grains seldom exceed 1/60 of an inch in diameter and occur closely interlocked producing a compact hard rock with high-crushing strength and low absorption. The valuable beds appear to be limited in extent and distributed in accordance with the general geolog-

ical structure of the region. The best quarry sites occurring on the top of the folds where the beds lie nearly horizontal and have suffered least from earth movements producing slips and irregular "bedding-joints."

Development-work has been progressing during the last year on the quarries at Summerfield on the Maryland and Pennsylvania Railroad where a good white marble in strong beds has been uncovered.

The variegated marbles of Carroll and Frederick counties which were formerly thought to occur in lenses are now known to form the tops of anticlinal domes of complicated structure. The exposures occur in low-lying level-bottomed valleys flanked by hills of metamorphosed shales and old volcanics. The samples obtained from the numerous small openings which have been made for the purpose of obtaining foundation stone and material for lime-burning show beautiful variegated marbles of fine even texture and pleasing tones of cream, pink, red, and blue. A few attempts have been made to obtain decorative stone from the better situated and more attractive deposits and these may prove successful in some instances. In most of the openings, however, the stone has been shattered by the use of explosives and careless quarrying in the extraction of stone for burning lime and for road-metal. Careful work with channelling machines or diamond drills at favorable points may yield good stone for decorative purposes, but the complicated close-folding of the beds, the development of numerous irregular open and hidden joints, and the irregular distribution of the colors make the successful development of large quarries doubtful.

Recent development work a few miles south of Union Bridge has shown a deposit of unusually attractive stone. This is of fine even texture with few flaws and of pleasing creamy white color and high luster. If further work confirms the present indications and the stone has sufficient strength this may prove an excellent site for the quarrying of decorative marble.

The cream-colored and variegated marbles of Washington County have been quarried with more or less success for several years and the output has added appreciably to the annual production of marble in the State. It is doubtful, however, if the deposits are of sufficient regularity and

extent to sustain a large and permanent industry in decorative marbles in this part of the State.

The "Potomac marble" or "calico rock" found along the eastern slopes of Catoctin Mountain in Frederick County has long been known and has been utilized from time to time since the early part of the last century. These deposits are of particular interest from the fact that they have furnished "the only true conglomerate or breccia marble that has ever been utilized to any extent in the United States." The stone obtained is unique in character and pleasing in appearance. The limestone and quartzite pebbles composing the rock vary in size from a fraction of an inch to a foot in diameter, and in color from gray to dark blue and contrast strongly with the dark red calcareous or silicious matrix in which they are imbedded. The rapid variation in hardness in the pebbles and the matrix, the irregularity of the beds and the varying cohesion of the cement to the pebbles make the extraction and polishing of this marble difficult and costly. The deposits may be worked from time to time with success, but prospects of continued commercial success must always remain more or less doubtful.

Serpentine or "Verde Antique" has been quarried in Maryland for many years, but the annual production has always remained small. As this rock enters into competition with some of the marble for interior decoration it has frequently been classed as a marble, although as far as the Maryland deposits are concerned it is in no wise related to the marble, however intimately interwoven with calcite veins it may be. The deposits are found in Cecil, Harford, Baltimore, Howard, and Montgomery counties, where they have been worked to a greater or less extent in the hope of obtaining good material for general building or interior decoration. The most thoroughly exploited deposits are those about Baltimore, at the Bare Hills; those on the banks of Broad Creek in the eastern part of Harford County; and a small area near Cambria in the northern part of the same county. That the stone is capable of furnishing beautiful slabs for decorative purposes has been clearly proven. The deposits on Broad Creek are situated in the midst of a large serpentine area, which extends from the Susquehanna southwesterly into Baltimore

County. The best rock is exposed in an almost inaccessible valley at a considerable distance from any railroad, and this has been too big a handicap to permit its being marketed at a profit.

The smaller deposits near Cambria, a small station on the Maryland and Pennsylvania Railroad not far from Cardiff, are better situated but the quarries are idle though not entirely abandoned.

VALUE OF THE ANNUAL PRODUCTION OF MARBLE, 1896-1907.

	Rough			Dressed				
	Building.	Monumental.	Misc.	Building.	Monumental.	Ornamental.	Interior.	Total.
1896	*	*	*	*	*	*	*	$110,000
1897	*	*	*	$130,000	*	*	*	130,000
1898	*	*	*	116,000	......	$625	$3,900	120,525
1899	*	*	*	75,000	......	300	1,700	77,000
1900	*	*	*	50,000	$20,000	...	......	70,000
1901	$8,100	.....	....	45,000	15,000	...	......	68,100
1902	30,000	$40,000	$3,000	.....	......	...	22,549	95,549
1903	28,180	25,065	30,427	.....	......	...	......	83,672
1904	50,000	23,814	....	.....	......	...	......	73,814
1905	7,168	.....	3,930	90.782	......	...	36,524	138,404
1906	91,000	16,400	9,495	59,000	......	...	......	176,495
1907	56,750	8,000	4,167	30,000	......	...	......	98,917

* Statistics incomplete in detail.

The output of marble during the last decade has been more or less variable, the fluctuations depending chiefly on the number of operators active, and the increased demand for structural materials incident to rebuilding after the Baltimore fire. The chief producers during the entire period have been the quarries of the Beaver Dam Company, located at Cockeysville, Baltimore County, and the quarries at Eakles Mills in Washington County. The fact that the latter quarries were operated only part of the year has decreased materially the marble output for 1907.

LIST OF MARBLE OPERATORS.

OPERATOR.	OFFICE.	QUARRY.
Beaver Dam Marble Co.	Baltimore	Cockeysville.
Washington Marble Co.	New York	Eakles Mills.
The Eastman Stone Co.	Baltimore	Whitehall.
Baltimore County Marble & Trading Co.	"	Baltimore.
Maryland-Alabama Marble Co.	New York	Benevola.
L. C. Rines	Eakles Mills	Boonsboro.
Whiteford Green Marble Co.	Whiteford	Cambria.
J. H. C. Watts	Baltimore	Cardiff.

LIMESTONE.

The blue and gray limestones of Paleozoic age have with a single exception never been quarried in Maryland as building stones except for local use. The most important and in fact the only limestone which has been used in prominent buildings is the Shenandoah limestone of the Hagerstown and Frederick valleys. This rock is usually a magnesian limestone containing alumina and graphite; it shows, however, a wide range in its composition.

This stone is usually of a deep blue color when freshly quarried but upon exposure there is slowly formed a thin white coating over the face of the rock, which brightens the color to a dove-gray, thereby greatly improving the appearance of the buildings. This change goes on uniformly and accordingly does not pass through the unsightly mottled stage.

Many areas in the Hagerstown Valley offer limestones which may ultimately prove of importance as building stones. Openings in the rock are made only for lime at the present time, and the methods of quarrying, which shatter the rock by heavy charges, make the exposures look less favorable for the production of building stone than is actually the case. If proper care in extraction were exercised, there is no doubt but that large blocks of limestone could be quarried in many places throughout the entire valley, which would in some instances work into a good grade of "black marble."

In the Frederick Valley little has ever been done towards quarrying the blue limestone for building purposes, as almost all of the stone which has been taken out has been burned for lime, which finds a ready market. The buildings in Frederick show that there has been some quarrying for building material, since several of them are built of limestone and almost all of them have limestone foundations or sills.

West of the Hagerstown Valley in Washington, Allegany, and Garrett counties there are three Paleozoic limestones, namely the Niagara, Helderberg, and Greenbrier. Of these the second is the only one which offers reasonable grounds for expecting good building material within its limits. The upper massive beds of the Helderberg which outcrop in five or six small bodies along the Potomac from Hancock to Cumberland,

and form a continuous belt from the latter point to Keyser, West Virginia, afford every indication that satisfactory building material may be obtained. Little if any work has been done in this formation because there have been no local demands.

Of the two remaining formations the Niagara is of such a nature that it cannot be used at all, and the Greenbrier is scarcely any better adapted to building purposes. Both formations occur in valleys with very few outcrops. The latter division has a single exposure on the Potomac between Keyser and Piedmont, West Virginia, and is imperfectly shown on Jennings Run and Braddocks Run. It is also injured for structural purposes by the pyrite which occurs scattered through it.

The value of annual output for the years 1896-1907 is shown in the accompanying table.

VALUE OF ANNUAL PRODUCTION OF LIMESTONE,† 1896-1907.

	Building.	Flagging, curbing, and paving.	Crushed road ballast and concrete.	Sold for flux and lime.	Miscellaneous rubble and rip-rap.	Total.
1896	*	*	*	*	*	$18,801
1897	*	*	*	*	*	16,924
1898	$10,768	*	$155,714	$3,446	$276	170,204
1899	8,896	*	7,292	869	647	17,703
1900	11,385	*	14,343	7,593	2,169	35,490
1901	14,138	$1,796	59,663	4,707	420	74,724
1902	16,953	1,575	95,966	9,097	3,022	126,613
1903	8,361	6,748	48,464	1,419	80	65,732
1904	12,836	1,036	111,147	2,466	902	128,421
1905	42,766	246	100,641	699	5,050	149,402
1906	8,393	779	160,109	*	765	170,046
1907	3,867	170	136,971	*	2,070	142,552

† Exclusive of lime.
* Statistics incomplete in detail.

The changes which have been made in the classification of the statistics gathered during the years represented renders the detailed discussion of the trade conditions impracticable. These changes have all been made to facilitate the gathering of more complete information. This end has been reached in the case of the larger operators but has been only partially successful with the smaller producers, many of whom are farmers who quarry only during those portions of the year when farm work is slack.

The demands for limestone, with the exception of that used for burning lime, are scattered and usually arise from local conditions. These come from the construction of local buildings and the limited use of limestone in pavements, sidewalks, and as a flux when local furnaces are in operation. The chief use of limestone is as crushed stone for surfacing the roads, for railroad ballast, and for concrete. The demand for road-metal is very constant, averaging about $40,000 a year, while that for railroad ballast and concrete is quite variable, depending upon the improvements made by the railroads of the region. On account of the extension of the Western Maryland Railroad westward from Cherry Run this demand was greatly increased in 1906 but with the completion of this work the demand is falling off.

The unit of measurement for limestone in the rough or crushed is the short ton of 2000 pounds, the perch, or the cubic yard. The content of the perch varies locally but is usually considered to be about 24.5 cubic feet or a ton and a quarter. The price obtained for the stone also varies locally, depending upon its quality and demand for the stone for lime-burning, and the proximity of the quarry to transportation lines. The usual range in price is from $.70 to $1.25 per perch or from $.60 to $1 per ton, and this remains fairly constant from year to year.

The largest operations for crushed limestone are situated at Pinesburg, Halfway, and Hagerstown in Washington County, and along the railroad in the vicinity of Frederick from Buckeystown to LeGore.

LIST OF LIMESTONE OPERATORS.

OPERATOR.	OFFICE.	QUARRY.
Fisher, Riley & Carozza	Baltimore	Green Spring Valley.
P. G. Zouck & Company	Cavetown	Cavetown.
J. C. Strock	Hagerstown	Cearfoss.
Cumberland Hydraulic Cement & Mfg. Company	Cumberland	Cumberland.
Henry Kinerlem	"	"
John D. Crum	Walkersville	Daysville.
Wm. F. Myers	Boring	Dover.
George F. Miner	Smithsburg	Edgemont.
D. M. Shinham	Hagerstown	Fairview.
Peter Brookey	Frederick	Frederick.
M. J. Grove Lime Company	Limekiln	Frederick and Limekiln.
R. Rush Lewis	Frederick	Frederick.
Charles A. Councilman	Glyndon	Glyndon.
Edward A. Cockey & Son	Owings Mills	Gwynnbrook.

OPERATOR.	OFFICE.	QUARRY.
S. P. Angle	Hagerstown	Hagerstown.
Clarkson Brothers	"	"
Hagerstown City Quarry	"	"
Hagerstown Macadam Company	"	"
D. E. Horst	Maugansville	"
Beverly Granite Company	Beverly, S. C.	Halfway.
Union Stone Company	York, Pa.	Halfway.
Frank P. Little	Hancock	Hancock.
LeGore Lime Company	LeGore	LeGore.
G. T. Baker	Marriottsville	Marriottsville.
P. P. Zepp	"	"
Daniel R. Miller	Maugansville	Maugansville.
D. K. Kramer	Mt. Pleasant	Mt. Pleasant.
Wm. Carbaugh	New Windsor	New Windsor.
Potomac Valley Stone Company	Hagerstown	Pinesburg.
D. D. Keedy	Keedysville	Rohrersville.
J. Wesley Creeger	Thurmont	Thurmont.
Joseph F. Moser	"	"
Vernon T. Smith	Lewistown	"
David G. Zentz	Thurmont	"
Wm. H. Staub	Union Bridge	Union Bridge.
Mordecai Fritz	Uniontown	Uniontown.
David Cramer	Walkersville	Walkersville.
Walter C. Zimmerman	"	"
Goodwin Lime Company	Westminster	Westminster.
Wm. R. Yingling	"	"
B. F. Shriver & Company	"	"
Mrs. Catherine Wagner	"	"
Wakefield Mill & Lime Company	"	"
The Maryland Quarry Company	Williamsport	Williamsport.
Jacob Eichelberger	Woodsboro	Woodsboro.

SANDSTONE.

Maryland possesses among the sandstones and quartzites of the State several which have been quarried locally, but only one of these, the Triassic, has attained any general reputation. The fact that the different sandstones are seldom very accessible or favored by location along a railroad or near large centers has doubtless been the main reason for the slight development of this industry. Still more important is the fact that the dark brownstones, which are the best situated for general trade, have fallen into disrepute and are no longer called for as formerly. This change of taste has been brought about by the uncertain wearing qualities of sandstones and the rather sombre tones produced after exposure to urban conditions.

The more important sandstones of the State are those of the Triassic, which occur along the eastern base of Catoctin Mountain in Montgomery,

Frederick, and Carroll counties; the heavy gray quartzites of the Blue Ridge; the white and buff sandstones of western Washington and Allegany counties; and the mica schists of Baltimore and Howard counties. Of these the first and last have been most frequently employed.

The Triassic sandstone has been quarried with more or less regularity near the mouth of Seneca Creek since colonial time and its use in the Smithsonian building at Washington after most thorough examination attests its excellence in color, texture, and durability. Unfortunately the beds differ among themselves in color, texture, and suitability, and at times stone from the different beds have been used indiscriminately. This has hurt the general reputation of the stone which, by careful selection, can produce entirely satisfactory results. Smaller quarries in both the gray and red sandstones of the Triassic have been worked in the vicinity of Taneytown for local use, but the product has never come into general demand.

The buff Oriskany sandstone of Allegany County has been used to some extent in Cumberland, but its lack of durability caused it to be soon replaced in public esteem by the harder white sandstone exposed in Wills Mountain. This rock now supplies all the local demands for foundation, backing, and trimmings in the better class of buildings in Cumberland, but its use has not become general throughout the State.

The mica schist which is characteristically developed along one side of the limestone valleys of Baltimore and Howard counties has gained some prominence in the immediate vicinity of its occurrence but the thinness of its beds and its numerous joints has prevented its successful introduction into the general trade.

The production of sandstone is slight and the production of individual quarries varies greatly according to the local demands. The greatest activity during the last few years has been in the vicinity of Taneytown where the quarries are small. Their output does not enter into the general trade. The larger quarries along the Potomac report little in the way of production compared with the amount of stone available and accessible.

The value of the annual production of sandstones from 1896 to 1907 is shown in the accompanying table.

VALUE OF THE ANNUAL PRODUCTION OF SANDSTONE, 1896-1907.

	Building.	Crushed road, railroad, and concrete.	Misc.	Total.
1896	*	*	*	$10,713
1897	*	*	*	10,000
1898	*	*	*	13,646
1899	$24,426	.....	.....	24,426
1900	6,655	.....	.....	6,655
1901	4,546	.....	.....	4,546
1902	7,210	$5,965	$2,230	15,405
1903	7,795	1,375	.....	2,170
1904	4,342	.....	4,656	8,998
1905	4,904	80	8,000	12,984
1906	3,661	108	5,764	9,533
1907	11,999	117	1,743	13,859

* Statistics incomplete in detail.

LIST OF SANDSTONE OPERATORS.

OPERATOR.	OFFICE.	QUARRY.
J. C. Brydon Bros. Co	Grafton, W. Va	Bloomington.
J. T. Bridges & Co	Hancock	Hancock.
B. S. Randolph	Berkeley Spgs., W. Va.	Dam No. 6.
Samuel Spangler	Taneytown	Kump.
Thos. D. Darby	Seneca	Seneca.
William Clutz	Taneytown	Taneytown.
T. H. Eckenrode	"	"
James D. Haines	"	"
James B. Reaver	"	"
O. T. Shoemaker	"	"

SLATE.

Deposits suitable for the production of roofing-slate have been found at several points within the limits of the State and quarries have been opened in the Peachbottom area of Harford County, at Hyattstown in Montgomery County, and at Linganore and Ijamsville in Frederick County. Slates from the latter county have proved pleasing in color and durable, but the public taste has been educated to certain characteristics for slate which these do not possess and they are of little or no commercial importance.

The only area of active operations at present is that in Harford County.

Peachbottom Slates.—The slate produced in the quarries of the Peachbottom district of Maryland and Pennsylvania is the most widely known

structural material manufactured within the limits of the State. Unfortunately Maryland has received little credit for its share in the industry although the majority of the productive quarries are situated within its limits. This has arisen from the fact that the shipping point for most of the quarries and the residence of many of the operators is Delta, Pennsylvania, a town lying at the foot of the ridge which supplies the stock for the manufacture of slate. Delta is much larger and better known than its Maryland associate, Cardiff, from which it is separated only by the State boundary.

The slate deposit forms a ridge about a third of a mile wide and nine to ten miles long, the southern third lying in Maryland. The structure of the slate beds is hard to make out. They appear to lie in a tightly-compressed syncline, the slate rock standing almost vertically. Judging from the location of the quarries Professor Dale thought there were three parallel beds running northeast and southwest, ranging from 75 to 120 feet across the cleavage and over 200 feet in depth. In the Maryland portion of the belt these beds are not clearly defined, the quarries showing good workable stock for a distance of two or three hundred feet across the cleavage.

The quality of the Peachbottom slate is well known to the trade as it has been widely used in this country since the inception of the slate industry. The stone is dark bluish-gray with a slightly rough but lustrous cleavage surface. Its color is absolutely unfading as shown by pieces which have been exposed to the weather for more than a century. It cleaves readily and works well for roofing-slate. It is not, however, as good for mill stock as some of the other slates on the market. The strength of the rock as determined by Merriam is greater than that from any other State.

Frederick County Slates.—The slates which have been worked occasionally at Ijamsville and Bennett Creek, near Thurston, Frederick County, are quite different from those of the Peachbottom district. The slates are purple to dark blue in color, possess only a slight to medium sonorousness or " ring," and are so soft that some at least can be sawn by hand. They are composed essentially of sericitic mica, chlorite, and

small amounts of other minerals. Some, if not all of these slates which have been worked at several points along a belt extending from near Dickerson, Montgomery County, to Union Bridge, Carroll County, are clearly old volcanics, flows and tuffs, which have been so changed as to present the appearance of metamorphosed sediments. The only deposit of these slates worked within recent years is that of the Bennett Creek Slate Company near Thurston, a small town at the foot of Sugar Loaf Mountain. This is at some distance from the railroad and its quality is not such as to permit the operators to overcome this handicap and compete with the other slates in the general market.

The annual production increased steadily from 1896 to 1905 when the output was more than twice that of the earlier date. During 1906 and 1907 the output has fallen off owing to the closing down of the Excelsior Quarry in 1905 and two serious "slides," one in the quarries of the Proctor Slate Company in 1906, the other in the Rees Quarry of the Peachbottom Slate Company of Harford County in 1907. The amount and value of the annual production from 1896 to 1907 are given in the accompanying table.

QUANTITY AND VALUE OF THE ANNUAL PRODUCTION OF SLATE, 1896-1907.

	Roofing slate. Number of squares.*	Value.	Average price per square.	Milled stock and misc. value.	Total value.
1896	15,557	$70,194	$4.49	$1,948	$72,124
1897	11,592	53,049	4.57	890	53,939
1898	18,332	80,786	4.35	1,454	82,240
1899	20,196	90,897	4.50	2,698	93,595
1900	27,158	126,271	4.65	2,402	128,673
1901	20,153	104,781	5.19	1,017	105,798
1902	22,569	117,155	5.19	929	118,084
1903	24,475	135,424	5.53	2,207	137,631
1904	22,628	131,245	5.80	2,727	133,972
1905	25,845	149,315	5.77	1,900	151,215
1906	25,288	129,965	5.13	1,004	130,969
1907	21,815	113,665	5.21	2,395	116,060

* The number of pieces in a square varies from 686 to 85 according to their size.

The number of squares, as given in the table includes both first and second qualities and the average price per square does not give a fair indication of the prices obtained for most of the stock. The output is about 90% No. 1 slates, for which the price per square varies according

to the size. The average is something over $6 for the first quality and $3.25 to $3.50 for No. 2 slates. During 1905 the price reached as high as $6.90 per square from certain quarries, when the average for individual producers reached over $6.60.

The stock during 1907 has been sold to a warehouse and selling association composed of the more prominent producers of the region. This has helped to maintain more uniform prices.

LIST OF SLATE OPERATORS.

OPERATOR.	OFFICE.	QUARRY.
Baltimore Peach Bottom Slate Company	Baltimore	Cardiff.
Cardiff Peach Bottom Slate Mfg. Co.	Delta, Pa.	"
Excelsior Slate Co. of Harford County	"	"
Peach Bottom Slate Co. of Harford County	"	"
Peerless Slate Co.	"	"
The Proctor Slate Co.	"	"
South Delta Peach Bottom Slate Co.	"	"
Bennett Creek Slate Co.	Washington, D. C.	Thurston.

CRUSHED STONE.

The increase in the demand and production of crushed stone during the last few years is one of the most prominent features brought out by the figures dealing with the stone industry of the State. This material is used exclusively for road-making, railroad ballast, and concrete.

Road-materials.—The materials used in road construction within the State vary widely in character, the question of transportation being so important a consideration that the best materials for this purpose cannot be used in regions far removed from the sources of supply.

The best road-material is the crushed basic igneous rock commonly known as trap, which is found throughout the Piedmont Plateau. This occurs in several types and includes gabbro, peridotite and pyroxenite, or their alteration product serpentine, and diabase. The gabbro or "nigger head" rock, as it is locally called, is most widely distributed, occurring in extensive areas in Cecil, Harford, Baltimore, Howard, and Montgomery counties. This rock is tough and difficult to work but affords a valuable and permanent road-metal. It varies in value according to its texture, the more even-grained granular varieties proving the

most satisfactory. The peridotites and pyroxenites occur in close association with the gabbro but are not as extensively developed. They are more easily worked than the gabbro but do not have its wearing qualities. Diabase, which has proved most useful for road-building purposes in New England and New Jersey, occurs in Maryland in long narrow outcrops in Baltimore and Howard counties and in more extensive areas in Frederick and Montgomery counties. The largest areas are found near the northern border of the state in the vicinity of Emmitsburg. The chief cementing material in all of these igneous rocks is the hydrous oxide of iron. The statistics for the output of "trap" are included under the head of granite.

A second group of road-building materials includes the marble, limestone, and calcareous sandstones and shales. Rocks of this character are found over widely separated areas throughout the Piedmont Plateau and the Appalachian Region, the most extensive and available deposits being found in the long narrow valleys north of Baltimore City and in the broader Frederick and Hagerstown valleys farther west. The cementing material in these rocks is the carbonate of lime. The rocks are easily worked but do not possess the durability of the igneous rocks when used as road-metal.

A third group of road-building materials competing with the crushed stone and used where the latter is too expensive includes the gravels and marls of the eastern and southern portions of the State. They belong to the late Mesozoic and Cenezoic formations and cover extensive areas in Cecil, Kent, Queen Anne's, Talbot, Anne Arundel, Calvert, Prince George's, and Charles counties, and with lessening importance extend into the more southern counties of the State. The gravels are rich in iron and the marls in carbonate of lime, which act as cementing materials. They afford less permanent road-metal than the igneous rocks, but when properly used are of great value in road-construction.

The granites and schists of the Piedmont Plateau and the sandstones and shales of the Appalachian region are employed for road-building purposes and are proving of local importance though lacking the cementing qualities of the materials of the three groups above described.

Ballast and Concrete.—The materials used for railroad ballast and concrete are, with the exception of the marls, the same as those employed in road-construction. Since a high bonding power is not required in railroad work and since cementing material is added in concrete the requirements are somewhat different from those of good road-metal. Granite, gneiss, and the more silicious rocks are equally serviceable with the traps and limestones in making concrete, and because of their more general distribution are more commonly used, especially when the cost of crushing and transportation become important.

During the earlier years of gathering statistics the industry of crushed stone was not sufficient to call for the separation of the output according to its use and the figures are accordingly given for the total annual value of each product. The following table shows the remarkable increase in annual production during the last decade.

VALUE OF THE ANNUAL PRODUCTION OF CRUSHED STONE, 1896-1907.

	Granite, trap, gneiss.			Limestone.			Sandstone.			Total.
	Road.	Ballast.	Concrete.	Road.	Ballast.	Concrete.	Road.	Ballast.	Concrete.	
1897		$41,999			*			*		$41,999
1898		83,888			$155,714			*		239,602
1899		106,636			7,292			*		113,928
1900		84,151			14,342			*		98,493
1901	$37,962	13,092	$50,404	$43,887	8,000	$1,776	..	.....	.....	155,121
1902	74,522	25,535	54,704	74,205	17,161	4,600	$10	$4,500	$1,455	256,692
1903	60,664	37,771	122,120	18,102	15,356	15,006	..	$1,375		270,394
1904	128,672	5,537	137,102	31,144	34,837	45,166	..	.....	.....	382,458
1905	133,599	8,046	212,592	31,823	36,210	32,608	..	80	.....	454,958
1906	125,655	5,803	171,869	30,582	110,503	19,024	8	100	.....	463,544
1907	280,741	29,717	492,846	66,248	61,881	8,842	10	.....	107	940,392

* Statistics incomplete in detail.

LIME AND CEMENT.

The various limestones and marbles of the State already described in discussing the stone industry are much more important as the foundation of the lime and cement industries. Both lime and cement are obtained from limestone and marble, and plants for their manufacture are scattered widely over the central and western parts of the State, the raw

material which is worked occurring in Baltimore, Carroll, Frederick, Washington, and Allegany counties. Plants for the burning of lime are found in each of these counties as well as in Howard, while mills for cement have hitherto been limited to Washington and Allegany counties, where there are good deposits of magnesian limestone suitable for the manufacture of natural cement. Many of the limestones are admirably adapted to the manufacture of Portland cement and hydrated lime but their manufacture in Maryland is only just projected.

The "high lime" and "magnesia" limestones are often intimately associated and they occur together in all the above-mentioned counties. The former is especially adapted to the manufacture of building and hydrated lime and Portland cement, while the latter has been extensively used as a natural cement rock.

LIME.

The burning of limestone at a temperature 850-1000° C. causes the loss of the contained carbon dioxide and the mass is changed to caustic lime, which is valuable for its cementing power and its action as a fertilizer when applied to the soil.

When this calcined or burned lime is exposed to air or moisture it slakes or loses its caustic properties by the absorption of the moisture and carbon dioxide from the air and ultimately becomes once more a calcium carbonate as it was before it was burnt. The properties possessed by the burned lime varies with the purity of the original rock. If this was a pure carbonate of lime the caustic lime will contain nothing but lime. These and such limes as contain less than 5% of impurities as magnesia, silica, and alumina are called "high limes" or "fat limes." Those containing more than this amount are called "lean" or magnesian limes. Most of the lime burnt in Maryland belongs to the first class, which is especially esteemed by builders and farmers.

The limestones used by most of the larger operators, as shown by their published analyses, are very pure, and the lime produced is said to run fully 98% pure lime.

The lime-burning industry is most extensively developed in the Frede-

rick Valley, which supplies two-thirds of all the lime produced in the State. Following the Frederick Valley in decreasing importance are Baltimore, Washington, Carroll, Allegany, and Howard counties.

The value of the production of lime by counties during 1907 is as follows:

Frederick	$261,423
Baltimore	95,030
Washington	22,366
Carroll	14,835
Allegany and Howard	1,060
	$394,714

The value of the annual production of lime from 1896 to 1907 is given in the accompanying table:

TABLE OF ANNUAL PRODUCTION OF LIME FOR THE YEARS 1896-1907.

1896	$250,477	1902	$326,417
1897	182,441	1903	320,494
1898	263,449	1904	309,079
1899	217,522	1905	360,247
1900	281,717	1906	350,460
1901	307,657	1907	394,794

The figures of this table show that during the period there has been a steady increase in the production, which reached its maximum in 1907, when the output exceeded that of the previous year by more than 12%.

A closer study of the returns for the year 1907 reveals several interesting facts. The units of measurement vary somewhat but the common practice is to use the standard bushel of 2150.42 cubic inches. The measurement is, however, generally made by weight, on the basis of 80 pounds to the bushel. At Texas and Cockeysville the bushel is estimated at 90 pounds. In a single instance sales have been made on the basis of 70 pounds to the bushel. Some of the larger producers sell in bulk by the ton which is figured as the equivalent of 25 bushels.

The price per bushel varies with the locality and with the quantity and quality of the product sold. The figures range from 7½ to 16 cents per bushel f. o. b. at the point of shipment. Nearly half of the producers quote at 12 cents. The higher prices are obtained in the Texas-Cockeys-

ville region, the lowest in inaccessible portions of the State, where the lime is of inferior quality.

Most of the burning is done in mixed feed, vertical, continuous kilns, or in the more rural districts in intermittent kilns, with coal, wood, or coke as fuel. The reports indicate that pea coal or anthracite siftings are most popular and that it requires a ton of coal for every 100 bushels or 4 tons of lime. A ton of coke appears to do the work of one and a third tons of coal; and a cord of wood that of a third of a ton of coal. At the prevailing prices the fuel charge is from 4 to 6 cents per bushel, and the total cost of burning, including the labor, from 5 to 7½ cents per bushel. This leaves a fair margin for the operator where the conditions are otherwise favorable.

The lime obtained in Maryland is used almost exclusively for agricultural purposes and as building mortar. Nearly 75% of the lime produced is used as a fertilizer, the remainder being used chiefly in building, a small amount going to chemical works or being used for miscellaneous purposes. The farmers expect as high-grade a lime for fertilizer as is demanded for building purposes but this is not always secured, judging from the lower value per bushel assigned to agricultural lime, wherever the grades are specified in the reports. The use of lime as a fertilizer received a serious setback with the introduction of the more popular phosphates which yield a more rapid return for the investment. There seems, however, to be a renewed interest in the use of lime and many farmers are returning to the practice of liming their fields. Should this movement become more general it will have a stimulating influence on the lime industry.

CEMENT.

The burning of limestones too rich in silica, alumina, and magnesia for high-grade lime if carried to the point of vitrification yields a slag or clinker which, when ground, acquires hydraulicity or the power to set when mixed with water. Such hydraulic cement has been extensively manufactured from the limestones of the Cayugan formations near Hancock, Cumberland, and Pinto, and from certain beds of the Shenandoah

limestone near Sharpsburg. The products from these industries have had an excellent reputation and have been largely employed both within and without the State. During the last few years several factors have seriously affected this industry. The burning of the mill of one of the larger operators and the occupation of its site by the extension of the Western Maryland Railroad has greatly reduced the output. Still more important has been the general change in practice by which Portland cement has supplanted the use of natural or rock cement. This has led to the temporary abandonment or conversion of most of the cement plants within the State. The change will, however, have but a temporary effect upon the cement industry in Maryland since there are many extentive deposits admirably adapted to the manufacture of Portland cement, and already several large mills for the manufacture of this product have been started and others are ready to enter the field as soon as the industrial and financial conditions become more favorable. The erection and operation of Portland cement plants such as are now proposed will have a stimulating influence on the whole industrial activity of the State.

The following table shows the quantity and value of the annual production:

ANNUAL PRODUCTION AND VALUE OF CEMENT (NATURAL AND SLAG), 1896-1907.

	Barrels.	Average price.	Value.
1896	250,000	$0.46	$115,000
1897	200,000	.52	104,000
1898	307,475	.44	136,489
1899	372,000	.42	154,800
1900	343,070	.41	140,028
1901	358,329	.54	180,665
1902	423,200	.38	161,180
1903	279,957	.53	148,619
1904	70,000	.51	36,250
1905	61,324	.54	33,494
1906	66,350	.49	32,675
1907*	......	...	......

* The figures for 1907 cannot be given without disclosing the product of individual operators since three or more plants have not reported production during the year.

LIST OF LIME AND CEMENT OPERATORS.

OPERATOR.	OFFICE.	QUARRY.
Wm. H. Everhart	Westminster	Bachmans Mills.
O. J. Keller Lime Company	Buckeystown	Buckeystown.
George M. Isanogle	Thurmont	Catoctin.
George W. Shinham	Hagerstown	Cearfoss.
Wm. D. Parlett	Clarksville	Clarksville.
James F. McKee	Clear Springs	Clear Springs.
Miss M. Bissel Price	Cockeysville	Cockeysville.
Denton S. Warehime	Westminster	Cranberry.
J. B. Gunning	Cresaptown	Cresaptown.
Robert Oss	"	"
* Cumberland and Potomac Cement Company	Cumberland	Pinto.
* Cumberland Hydraulic Cement & Mfg. Company	"	Cumberland.
Joseph Dressman	Long	"
C. A. L. Miller	Cumberland	"
John D. Crum	Walkersville	Daysville.
T. Turnbaugh	Boring	Dover.
George W. Hose	Clear Spring	Dry Run.
Brown & Bachtell	Smithsburg	Edgemont.
Fountain Rock Lime Co. (J. W. Stimmel)	Woodsboro	Walkersville.
M. J. Grove Lime Company	Limekiln	Frederick and Limekiln.
R. Rush Lewis	Frederick	Frederick.
Gilmer Schley	"	"
G. Dallas Walters	Fulton	Fulton.
Charles A. Councilman	Glyndon	Glyndon.
Edward A. Cockey & Son	Owings Mills	Gwynnbrook.
* Maryland Portland Cement Company	Hagerstown	Security.
W. M. Widmyer	Hancock	Hancock.
Daniel Sunday	Hansonville	Hansonville.
George W. Yost	Clear Spring	Clear Spring.
T. Guy Nichols	Brookville	Highland.
G. A. Scaggs	Highland	Laurel.
LeGore Lime Company	LeGore	LeGore.
M. Frank McAleer	Walkersville	McAleers.
G. T. Baker	Marriottsville	Marriottsville.
Daniel F. Roddy	Mt. St. Mary's	Motters.
George H. Strine & Son	Mt. Pleasant	Mt. Pleasant.
Mordecai C. Jones	"	New London.
John W. Myers	New Windsor	New Windsor.
Potomac Valley Stone & Lime Company	Hagerstown	Pinesburg.
D. D. Keedy	Keedysville	Rohrersville.
J. Hubert Wade	Boonsboro	Sharpsburg.
John T. Dutterer	Silver Run	Silver Run.
Wm. A. Leppo	"	"
George N. Besore	Smithsburg	Smithsburg.
Rohrer Bros.	"	"
Wm. C. Dittman	Texas	Texas.
Wm. P. Lindsay	"	"
J. Wesley Creeger	Thurmont	Thurmont.
Joseph F. Moser	"	"
F. A. Roddy	"	"
David G. Zentz	"	"
Wm. Haines	Union Bridge	Union Bridge.

* Cement Operators.

OPERATOR.	OFFICE.	QUARRY.
Wm. H. Hyde	Union Bridge	Union Bridge.
Wm. H. Staub	"	"
Mordecai Fritz	Uniontown	Uniontown.
Milton S. Zimmerman	Walkersville	Walkersville.
Walter C. Zimmerman	"	"
David A. Devilbiss	"	"
Goodwin Lime Company	Westminster	Westminster.
Wm. B. Yingling	"	"
David Robertson	"	"
B. F. Shriver & Company	"	"
Wm. A. Roop	"	"
Mrs. Catherine Wagner	"	"
Wakefield Mill & Lime Company	"	"
Charles F. Trescher	Cumberland	Winchester Bridge.
S. W. Barrick & Son	Woodsboro	Woodsboro.
Jacob Eichelberger	"	"

FLINT AND FELDSPAR.

Maryland, as a State, is well provided with porcelain materials such as flint or vein quartz, feldspar, and kaolin. These are chiefly developed in central Maryland and mined in this region only. They are abundantly present over wide areas but only occasionally are they sufficiently free from colored minerals and coloring matter to meet the requirements.

FLINT.

The flint or quartz is derived from unusually large and pure masses of vein quartz or from portions of the gneiss and granite along their contact where the original rocks have been reduced to white pulverulent quartz. Flint has been sought most successfully in Cecil, Harford, Baltimore, and Howard counties. Most of the material occurs as veins intersecting the country rock, generally gabbro, serpentine, or granite. Where the vein quartz is utilized it is necessary to grind the material to a flour and to facilitate this grinding it is customary to roast the blocks of quartz and then cool them suddenly by pouring on water, as is done at the flint works at Conowingo, Cecil County. The flint from the granite-gneiss contacts require no roasting but need to be ground to a flour to meet requirements. The flint flour is shipped in bags to different points within and without the State, chiefly to Trenton, New Jersey, where it is employed in the manufacture of porcelain, crockeryware, wall and sandpaper, scouring soap, tiles, and paints.

FELDSPAR.

The feldspar, or "spar", occurs in pegmatite dikes which are found abundantly developed throughout the eastern portion of the Piedmont plateau in Cecil, Harford, Baltimore, Carroll, and Howard counties. The material mined is either microcline or orthoclase furnishing the so-called "potash spar," or a plagioclase furnishing the "soda spar." The presence of pegmatite dikes in which these minerals occur may be easily recognized by the numerous coarse-grained boulders scattered over the surface or by the chalky white streaks in the road-cuts. They are very frequently found near the borders of the serpentine, gabbro, or granite, and occasionally in the marbles. The valuable dikes are those in which the "spar" is free from colored minerals and relatively free from quartz. Pegmatites of this character are being worked in Cecil County along the Mason and Dixon Line and in the valley of the Patapsco in Baltimore and Howard counties. All of the material has to be hand-culled to free it from ferruginous matter which would stain the potteryware during burning and the output is shipped in a crude state chiefly to Trenton, N. J., Wilmington, Del., Baltimore, and East Liverpool, Ohio, where it is ground and used in the extensive pottery works.

LIST OF FLINT AND FELDSPAR OPERATORS.

OPERATOR.	OFFICE.	QUARRY.
A. M. Benzinger	Woodstock	Woodstock.
W. Howard Brown	"	"
Cavey & Cavey	"	"
Deland Mining & Milling Company	Havre de Grace	Baldfriar.
Harry Fairbank	Woodstock	Woodstock.
Alpheus F. Ide	"	"
John Mitchell	"	"
Parlett & Parlett	"	"
Read & Cavey	"	"
E. E. Fagan	Gwynn Oak, Baltimore	Hollofields.
Wm. T. French	Woodlawn Station	Woodlawn.
Golding Sons Co	Trenton, N. J.	Rock Springs and Davis Station.
Guilford & Waltersville Granite Co	Baltimore	Woodstock.
W. F. Patterson & Son	Henryton	Henryton.
Thomas & Son	Westminster	Westminster.
Eureka Mining & Operating Company	Trenton, N. J.	Granite.
Pennsylvania Feldspar Company	Philadelphia	Conowingo.
Maryland Silicate Mills	Baltimore	Louisville.
H. Clay Whiteford & Co	Flintville	Flintville.
Glen Morris Supply Company	Glen Morris	Glen Morris.
Harford County Flint Company	Conowingo	Conowingo.

The following table brings out the unevenness of this unusual mineral industry. The figures show a considerable and irregular range in the quantities produced in different years and the value of that which was sold. Part of this irregularity is real, part is due to the fact that many of the operators quarry or mine in a small way without keeping accurate records of amounts obtained or prices asked. According to the figures the average price per ton of the crude flint has varied from $4 in 1902 to $.88 in 1907, and that of the ground from $8.26 in 1903 to $6.59 in 1907. The average price of crude feldspar has been more constant, ranging from $3.10 in 1903 to $3.82 in 1907. This latter figure was exceeded by a few cents in 1904, but this may have been due to the inclusion of a small amount of ground spar with the crude. The falling off in the production of flint in 1907 has been due to the destruction by fire of two of the plants and the burning of the bridge across the Susquehanna river between the mill and some of the producers, more than to a marked decrease in demand.

ANNUAL PRODUCTION AND VALUES OF FLINT AND FELDSPAR.

	Quartz (Flint).							Feldspar.			Total flint and feldspar.
	Crude quantity tons.	Value.	Average price per ton.	Ground quantity.	Value.	Average price per ton.	Total.	Crude quantity tons.	Average price per ton.	Value.	
1900	1,904	$2,975	$1.56	4,400	$27,300	$6.25	$30,275	1,643	$1.90	$3,145	$33,420
1901	1,818	2,929	...	5,030	37,000	7.35	39,929	[3,500]	...	[6,000]	45,929
1902	1,835	7,436	4.00	8,500	66,700	7.83	74,136	5,560	1.60	9,100	83,236
1903	1,055	2,475	2.34	8,480	69,880	8.26	72,355	4,591	3.10	14,543	86,898
1904	720	2,177	3.00	6,524	44,100	6.75	46,277	13,492	3.90	52,590	98,867
1905	1,050	2,637	2.50	6,450	45,700	7.10	48,337	7,768	3.50	27,215	75,552
1906	1,050	2,725	2.68	11,200	89,600	8.00	92,325	10,229	3.37	34,507	126,832
1907	1,370	1,100	.88	5,650	37,250	6.59	38,350	13,729	3.82	52,510	90,860

SAND AND GRAVEL.

Sand, and to a less extent, gravel, are widely distributed throughout the State, the better grades being found chiefly in the Cretaceous, Tertiary, and Quaternary formations of the Western and Eastern shores and in the Paleozoic formations of western Maryland. Sand also occurs on the beds of the tidal streams and estuaries, from which it has been extensively dredged in recent years. The sands of Maryland are employed

as building-sand, glass-sand, molding-sand, engine-sand, and in the manufacture of sand-lime brick. Gravel and sand are used also for concrete work and at times for road-building.

Building-Sand.—Building-sand is the most widely distributed type of sand and occurs adjacent to nearly all of the leading centers of population. Sand of homogeneous texture but not of remarkable purity is required for use in making mortar. Building-sand is in part secured from the various geological deposits in place and in part dredged from the beds of the streams and estuaries where the sorting properties of the water have produced large accumulations of relatively pure sand. The Coastal Plain deposits of Cretaceous, Tertiary, and Quaternary age afford good building-sand although much the larger amount for use in Baltimore City has been secured in recent years from the beds of the tidal streams and estuaries in Baltimore and Anne Arundel counties, and from the bed of the Potomac River in Prince George's County for use in Washington.

Concrete Sand and Gravel.—With the great increase in the use of Portland cement the demand for sand and gravel in concrete construction has grown largely in recent years and they are destined to have a far greater use for this purpose in the future. The sand used is similar to that employed as building-sand and both are supplied from the same pits. The most important gravel beds occur in the Cretaceous and Quaternary deposits and are found largely along a belt extending from the northern section of the State to the District of Columbia striking across the head of tide, and between the various tidal streams and estuaries of the same area although spreading both to the east and west along the divides.

Glass-Sand.—Glass-sand is found in the Cretaceous (Magothy formation) deposits of Anne Arundel County and in the Silurian (Tuscarora formation) and Devonian (Oriskany formation) deposits of Washington and Allegany counties. The glass-sand of Anne Arundel County is chiefly confined to the upper part of the Severn River region where it has been extensively worked on both the northern and southern banks. The western Maryland glass-sand deposits have not been exploited thus far although the same formations (more particularly the Oriskany for-

mation) in Pennsylvania and West Virginia contain the most important beds of glass-sand in the eastern United States.

Sand constitutes from 50% to 60% of the glass-furnace charge and nearly three-quarters of the finished product, and slight changes in the character of the raw material may seriously affect the color, hardness, and brilliancy of the glass. The purest sands are required for flintware and optical glass. Even for plate and window glass it is essential that the sands shall not carry more than two-tenths of one per cent of ferric oxide. Lower-grade glass for bottles, jars, etc., requires less pure raw materials but all glass-sand appears practically free from impurities. "In examining sand, in order to ascertain its value for glass-making purposes, inspection with a magnifying glass is the best preliminary test. The following points should be observed: The sand should be nearly white in color; it should be of medium fineness (passing a 20 to 50-mesh horizontal sieve); the grains should be uniform in size, even, and angular, or, less preferably, they may be rounded. A simple chemical test may be employed by heating the sand in a dilute acid. Effervescence indicates the presence of lime; loss of color shows the presence of clay impurities. Iron in the most minute quantity may be detected by dissolving sand in hydrofluoric acid and adding potassium ferrocyanide, which produces a blue precipitate if iron is present. Complete quantitative analyses as well as a furnace test should be made as final determination of the character of a prospective glass-sand."

Molding-Sand.—Molding-sand has been found in Anne Arundel, Baltimore, Cecil, and Kent counties, but it has not been extensively employed for such purpose up to the present time. Large deposits of good molding-sand are reported from the Cretaceous (Monmouth formation) at the mouth of the Magothy River in Anne Arundel County, while a less extensive deposit of very high-grade molding-sand has been worked from time to time near Catonsville in Baltimore County. Several of the Coastal Plain formations afford valuable materials of this character.

Engine-Sand.—Engine-sand for locomotives and trolley-cars may be furnished by any angular quartz sand of medium grain and fair degree of purity. It is largely supplied by glass-sand works from the inferior

grades of glass-sand, although many local sands are also employed for the same purpose. Many of the Maryland sands are suitable for engine-sand and a great variety of kinds are in use.

Miscellaneous Uses.—Sand of good quality has in recent years been used to a considerable extent in the manufacture of sand-lime brick both at Cumberland and in Baltimore City. Brick of this type are manufactured from pure angular quartz sand mixed with lime, the usual proportion being 95% sand and 5% lime. The materials are pressed and then put through steam ovens of high temperature after which they are ready for use.

The gravels are used to some extent in road-building, being well adapted to the latter purpose when containing a natural iron cement and when from their proximity the transportation charges can be kept low.

There are innumerable uses to which sand in small quantities is put in the various industries, but as no record in most instances is kept of the amount employed nothing of particular interest can be derived from their detailed discussion.

VALUE OF THE ANNUAL PRODUCTION OF SAND AND GRAVEL.

1904	1905	1906	1907
$219,268	$436,828	$285,797	$277,106

Very incomplete records of the use of sand have been available until within the last few years. It is known that the amount employed was very much less in the early part of the period under discussion than in recent years, particularly since the enormous increase in the consumption of building-sand brought about by the rebuilding of Baltimore after the great fire of February, 1904. The production for the year 1905 was the largest in the history of the sand and gravel business.

LIST OF SAND AND GRAVEL OPERATORS.

OPERATOR.	OFFICE.	PITS.
Acme Sand Co	Baltimore	Spring Gardens, Magothy River, and Curtis Creek (dredging).
Columbia Granite & Dredging Co	Washington, D. C.	Marshall Hall.
Potomac Dredging Co	Washington, D. C.	Potomac River (dredging).
Excelsior Brick & Pottery Co	Halethorpe	Arbutus.
Adam Joh & Bro	"	Benson Ave.

OPERATOR.	OFFICE.	PITS.
John C. Leonard	Baltimore	Baltimore.
J. T. Bridges & Co	Hancock	Hancock.
P. L. Hopper	Havre de Grace	Conowingo.
B. S. Randolph	Berkeley Spgs., W. Va.	Dam No. 6.
The Cumberland Granite Brick Co	Cumberland	Cumberland.
Contee Sand & Gravel Co	Laurel	Laurel.
Brennan Sand Co	Philadelphia, Pa.	Robinson.
Foltz Bros.	Waynesboro, Pa.	Rock Forge.
James D. Haines	Taneytown	Taneytown.
Daniel Oller	Waynesboro, Pa.	Leitersburg.
Fred. Link	Halethorpe	Halethorpe.
American Sand & Stone Co	Baltimore	
Northwestern Sand & Contracting Co	"	Severn Station.
Charles Smith	Waynesboro	St. Mary's.
St. Mary's Gravel Co	Norfolk, Va.	"
H. L. Thomas	"	Gibson Island.
W. T. Manning	"	near Laurel.

ORES.

GOLD ORE.

Gold has been found in the crystalline rocks of Maryland, the first discovery being made near Sandy Springs in 1849. Since then it has been found in greater abundance in the southern part of Montgomery County near the Great Falls of the Potomac, where numerous attempts have been made to mine it successfully. Gold has also been reported from Baltimore and Cecil counties and the serpentine region about Conowingo and Rock Springs suffered from unwarranted attempts at mining this metal a few years ago.

The gold at Great Falls occurs in the quartz-filled lenticular veins in the crystalline rocks of the Piedmont in the form of native gold and is associated with pyrite, galena, and tetradymite, a telluride of bismuth. The occurrence is of interest as forming the most northerly point of the Appalachian gold belt which extends from Maryland across Virginia, the Carolinas, and Georgia into Alabama.

Several mines and prospects have been opened in the State, all of them in the vicinity of Great Falls, Montgomery County, about 15 miles northwest of Washington, D. C. Several of these have been equipped with machinery but none of them have proved very successful. Two mines reported more extensive operations in 1905. The Maryland mine of the Maryland Gold Mining Company has sunk a shaft to the depth of 180

feet and is equipped with a 10-stamp mill, the Anderson Mine is not as fully developed. Neither of these reported any product in 1907.

The difficulties which have hitherto prevented successful workings have been the "pockety" or scattered occurrence of the ore, some of which affords very rich samples, and the hardness of the gangue which increases the cost of operation and the wear on the machinery. The annual output of gold has varied widely according to the temporary activity or idleness of the operators, ranging from $15,000 to nothing.

LIST OF GOLD OPERATORS.

OPERATOR.	OFFICE.	MINE.
Capital Gold Mining & Development Company	Cropley	Cropley.
R. Scott Allen	"	"
Maryland Gold Mining Company	"	"
Great Falls Gold Mining Company	Washington, D. C.	Great Falls.

COPPER ORE.

The copper found in Maryland occurs in the Blue Ridge district and in the crystalline rocks of the Piedmont of Frederick, Carroll, Howard, and Baltimore counties. In the Blue Ridge district the deposits are in or associated with the altered, dense, heavy trap rock which is known as the Catoctin schist. In the western Piedmont region they are either in the limestone or schists and in every instance examined are closely associated with igneous rocks. The various openings appear to lie in zones or belts. The first or westernmost zone extends along the Linganore Hills from New London in Frederick County through Liberty to Union Bridge, the ore occurring both in the limestones and slates or in the altered rhyolites. The second zone runs northeast from Sykesville in Carroll County to and beyond Finksburg on the Western Maryland Railroad, the ore occurring in slates and schists, the latter probably altered igneous rocks. A third deposit is found in the Bare Hills of Baltimore County, the ore occurring in an altered gneiss or schist near the contact with serpentine.

The copper is found as the sulphides, bornite, or chalcopyrite, and as the carbonate, malachite. Prior to the finding of the richer deposits of Michigan, Arizona, and Montana, Maryland ores were sufficiently sig-

nificant to make the State of some importance as a copper producer and recently the introduction of new processes has revived the interest in the Maryland deposits. It is doubtful, however, if the copper industry will ever prove of any magnitude in the State as the margin of profit is very narrow and likely to be wiped out by careless management or fluctuations in the market value of the copper.

At present only one producer, the Liberty Mine, worked by the Virginia Consolidated Copper Company, reports any output.

COPPER OPERATOR.

OPERATOR.	OFFICE.	MINE.
Virginia Consolidated Copper Co.......	Union Bridge	Liberty.

IRON ORE.

The iron ores of the State were worked in colonial days and for more than a century afforded the basis for the chief mineral industry of Maryland. Numerous references to the iron ores are found in the old records and even early in the eighteenth century there was much activity in iron manufacture. The Principio Company, one of the most important commercial enterprises in the early days of Maryland, was organized in 1722 and began the erection of a furnace in Cecil County near the mouth of Principio Creek. In 1761 the Governor and Council of Maryland reported to the Commission of the Board of Trade and Plantations in England that there were 18 furnaces and 10 forges in the Province which made 2500 tons of pig iron per year. During the Revolutionary War the furnaces and forges of the Principio Company supplied bar iron and cannon balls to the Continental Army. The Principio Company during the War of 1812 produced cannon balls and hardware, and guns as large as 32-pounders were made for the government.

Many furnaces were built in other sections of the State during the eighteenth and early portion of the nineteenth centuries, but nearly all of them have been abandoned. Among the most important of these furnaces is the Catoctin furnace in Frederick County, which was built in 1774 and furnished guns and projectiles to the Continental Army during the Revolutionary War. It has been in operation from time to

time down to very recent years. Furnaces were also built in Harford, Prince George's, Washington, and Allegany counties and in Baltimore City.

The last furnace in the State to employ Maryland ores to any great extent has been the Muirkirk Furnace at Muirkirk, Prince George's County, which, although not in blast at the present time, has produced pig iron of great tensile strength. This iron has been largely used by the U. S. Government at the Watertown Arsenal and Washington Navy Yard for the manufacture of gun-carriages and armor-piercing projectiles as well as by private companies requiring an iron of great strength, it being guaranteed to stand 30,000 pounds to the square inch, many tests showing 40,000 pounds and more.

Great furnaces of modern type have in recent years been constructed near Baltimore at Sparrows Point by the Maryland Steel Company, but they employ ores secured from outside the State, the chief supply coming from deposits in Cuba.

Red and Brown Hematites.—The red and brown hematites, the latter largely predominating, are found in the crystalline rocks of the Piedmont Plateau and in the Paleozoic sedimentary deposits of the Appalachian Region. The most important beds occur in Frederick and Carroll counties, which to-day furnish the only shipping ores in the State. The red and brown hematites of Washington and Allegany counties, although mined during the third quarter of the last century at a number of points, have been entirely abandoned.

The discovery several decades ago of much more extensive deposits in other sections of the country, in Michigan, Minnesota, and Alabama, as well as in Cuba, coupled with the incidental extension and cheapening of transportation resulted in driving out the old charcoal furnaces and thus left no place for the lean ores of Maryland. Within the last few years, however, there has been a revival of interest in the abandoned iron-ore deposits of the eastern seaboard states and already their importance as sources of ore supply has come to be recognized. It is highly probable that the Maryland brown hematite will be mined again

as it seems possible that these deposits when exploited will be found to afford a workable supply of commercially valuable ore.

Siderite.—The siderite or carbonate iron ore is confined to the Cretaceous (Arundel formation) deposits of the Coastal Plain, being found in Cecil, Baltimore, Anne Arundel, and Prince George's counties and in Baltimore City. The ore occurs in lenses in the clay, nodules of large and small size and ledges of the siderite at times making up the main beds of the deposits. The carbonate iron ore is known to the miners as "white ore" while the hydrous oxide iron ore derived from the same is referred to as "brown ore." These ores have been worked since colonial days, and it was from such deposits that the material used in the Principio Furnace was derived. Although mined for two centuries much still remains, the larger and more accessible beds having, however, been largely exhausted.

Pyrites.—Iron pyrites occurs in the Magothy formation on the Magothy River and was at one time roasted for the manufacture of sulphuric acid. The deposits are not sufficiently large, however, to justify the continuance of the industry. The ore occurs in isolated masses or as irregular crusts or layers in carbonaceous beds.

The annual output of iron ore in Maryland has varied very largely in recent years. It has greatly declined in amount whenever the Muirkirk Furnace, the only furnace in the State in recent years using Maryland ore, has been temporarily closed, as has been the case during the years 1906 and 1907. The chief production of iron ore at the present time comes from the brown hematite deposits of Bachman's Valley in Carroll County and from similar beds near the old Catoctin Furnace in Frederick County. These ores are shipped outside the State going to furnaces in nearby districts of Pennsylvania.

LIST OF IRON ORE OPERATORS.

OPERATOR.	OFFICE.	MINE.
Mason & Dixon Mining Company	Shrewsbury, Pa.	Bachman's Mills.
Ebbvale Mining Co.	Hanover, Pa.	Ebbvale.
Charles E. Coffin	Muirkirk	Muirkirk.
Jos. E. Thropp	Everett, Pa.	Thurmont.

MINERAL PAINTS.

Mineral paint has been mined at several points in Maryland from widely different geological formations. It has never developed into a large industry although capable of much greater development. It is closely associated with the deposits of hydrous oxide of iron of which it is largely composed. It is commercially known as ochre and is yellow, red, or brown in color, dependent in part on the presence of other ingredients.

The brown hematite deposits of Frederick, Carroll, and Howard counties have been important sources of ochre although little or no exploitation of the beds is now in progress. Considerable shipments have been made from time to time from the Catoctin Furnace pits as well as from points in Carroll and Howard counties.

The largest deposits of mineral paint are, however, in the Patapsco and Arundel formations in Anne Arundel and Prince George's counties, which have afforded at times a considerable output of this material. It occurs as a fine and highly ferruginous clay which can be easily dug after the overburden has been removed.

The finished product includes metallic paint, mortar colors, venetian red, umber, sienna, and ochre.

MINERAL PAINT OPERATOR.

OPERATOR.	OFFICE.	PITS.
Macneal's Varnish & Color Works......	Baltimore	Baltimore and vicinity.

MISCELLANEOUS ORES.

There are several other mineral substances which are not being worked to-day within the State. None of these products will probably give rise in the future to industries of great magnitude, because of the insufficient supply of the material. Several of them have been worked from time to time but none, except chrome, has ever proved of real economic importance.

Chrome.—The chrome industry in Maryland originated in the discovery in 1827 of chrome ore in the serpentine of the Bare Hills in Baltimore County. Subsequently other deposits were found associated

with the serpentine in Harford and Cecil counties, as well as at other points in Baltimore County. Between 1828 and 1850 Baltimore supplied most of the chrome ore consumed by the world, the remainder coming from the serpentine and platinum washings of the Ural Mountains. After 1850 the foreign demand for Baltimore ore declined gradually until 1860, after which time almost none has been shipped abroad. The reason for this was the discovery in 1848 of great deposits of chromite in Asia Minor. This region now largely supplies the world's demand. Since 1886 practically nothing has been done with the chrome deposits of Maryland, although Baltimore is still one of the most prominent centers for chromium salts.

Lead and Zinc.—Traces of galena and zincblende were early noted in the quarries at Jones Falls in Baltimore County, but much more decided indications of these minerals occur in connection with the crystalline limestone in the western part of Carroll and the eastern part of Frederick County, where attempts have been made to mine them in the region to the southwest of Union Bridge. In spite, however, of the frequent traces of both these minerals throughout central Maryland, it may be confidently asserted that neither will probably be found to occur in amounts that will repay the expense of mining them.

Manganese, Antimony, and Molybdenum.—The traces of these metals which have been detected in Maryland are even more insignificant than those of lead and zinc. Manganese was once mined a short distance west of Brookville in Montgomery County, but the deposit was not sufficiently extensive to be profitable. More recently manganese has been reported from Allegany County. Specimens of the sulphide of antimony have been obtained in the Middletown Valley but nothing is known of its occurrence or extent. The earliest discovery of molybdenite mentioned on this continent was made at the Jones Falls gneiss quarries in 1811, but the deposit was not sufficient to be of economic value.

MINERAL WATER.

Mineral water is chiefly produced in Maryland for table use. Several springs bear a high reputation for the purity of their water and the

industry has been in a flourishing condition in recent years. The waters find their chief market in Baltimore and Washington although some are sold outside the State.

Nearly all of the well-known springs are located in the crystalline rocks of the Piedmont Plateau, only a few being in the Appalachian Region and Coastal Plain. The chief springs in the Piedmont are the Chattolanee spring in Baltimore County and the Tacoma and Carroll springs in Montgomery County, the latter a thermal spring of saline mineral nature which has been regarded as having medicinal properties. There are numerous cold Chalybeate springs scattered throughout western Maryland but there has been as yet no attempt to introduce their waters or to develop the properties upon which they are situated. The chief spring in the Coastal Plain is the Mardela spring in Wicomico County, the waters from which have been placed on the market. Several other springs possessing a local reputation are reported from the eastern and southern counties, as at Blackistone Island in the Potomac and a sulphur spring situated at St. Michael's in Talbot County. Summer resorts have sprung up around some of the springs, the pure quality of the water being advertised as an important feature.

ANNUAL PRODUCTION OF MARYLAND MINERAL WATER, 1896-1907.

1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
$58,339	$21,185	$29,779	$13,045	$36,849	$57,680	$45,100	$45,918	$44,820	$44,627	$58,334	$86,606

The annual production of mineral waters has risen very much in recent years as shown in the table given above, the largest output being in 1907. The water most extensively used is the Chattolanee water which has a high reputation in Baltimore.

LIST OF SPRINGS.

OPERATOR.	OFFICE.	SPRINGS.
Altamont Spring	Washington, D. C.	near Deer Park.
Carroll Springs	Forest Glen	Forest Glen.
Chattolanee Springs	Baltimore	Chattolanee.
Mardela Mineral Spring	Mardela	Mardela.
Rockhill Indian Spring	Rockville	Rockville.
Takoma Spring	Takoma Park	Takoma Park.
Blue Ridge Spring	Baltimore	Blue Ridge Mountains.
White Rock Mountain Spring	"	"

MISCELLANEOUS MATERIALS.

Silica.—The diatomaceous earth bed found at the base of the Miocene deposits in Anne Arundel, Calvert, and Charles counties has been dug extensively for commercial uses from time to time. The material is known in the trade under the name of "silica," "infusorial earth," or "tripoli." It forms a bed from 30 to 40 feet in thickness at the base of the Calvert formation, the lowest division of the Maryland Miocene. It has been traced across southern Maryland from the shores of Herring Bay on the Chesapeake to Lyons Creek on the Patuxent and thence to Pope's Creek on the Potomac River.

Infusorial earth is composed of the minute shells or tests of microscopic plants known as diatoms. This material was first reported from the region of Richmond and for that reason received the name of "Richmond earth," under which term it is often referred to in the literature. It has also been called "Bermuda earth" from its occurrence at Bermuda Hundred on the James River.

Silica is used as an abrasive, being employed in the manufacture of polishing powder and it also affords an excellent non-conducting cover for steam-pipes. From its extremely porous character it has been used in the manufacture of dynamite cartridges. Silica was first worked on the Patuxent River in 1882.

It has been difficult to secure accurate statistics regarding the annual production of silica from the two Maryland points from which shipments have been made. The chief producer at the present time is the Maryland Silicate Company of New York City which has largely operated in recent years at Lyons Creek on the Patuxent River.

SILICA OPERATOR.

OPERATOR.	OFFICE.	QUARRY.
Maryland Silicate Co	New York	Lyons Creek.

Marl.—Marl occurs in the Eocene and Miocene formations of eastern and southern Maryland. The former being known as *greensand marl* and the latter as *shell marl*. They have never been developed, however, except for local uses.

The Eocene greensand marl is glauconitic, the mineral glauconite pro-

ducing what is known as a greensand. It contains a small percentage of available phosphates and alkalies and when shells are present in the deposits, as they generally are, lime as well; some marls, however, being almost devoid of that ingredient while others contain it in large proportion. The most important Eocene marls are found in Anne Arundel, Prince George's, and Charles counties, although they are not lacking in Kent County also.

The Miocene shell marl contains a variable percentage of lime dependent on the number of calcareous shells of fossil organisms in the deposits. Some of the most fossiliferous beds, especially where the shells have been thoroughly weathered, afford an excellent fertilizer for those lands deficient in lime. The shell marl occurs abundantly in Queen Anne's, Caroline, Talbot, Calvert, and St. Mary's counties.

It is very difficult to gain any adequate idea as to the production of marls during a given year so that it is necessary to assume an average value for the annual product. A small part of the marl is used here and there for road-building purposes, particularly in Caroline County, where a bed admirably adapted for that purpose has been found on the bank of the Choptank River near Denton. It could be employed elsewhere with advantage. The average annual value of the marls dug probably does not exceed $3000.

Mica.—The coarse pegmatites which abound in many parts of the eastern Piedmont region afford good-sized plates of light-colored mica (muscovite), and attempts have been made to secure commercial quantities of this in both Harford and Howard counties, but they have not been successful. This has been due to the irregular abundance of the larger-sized crystals or "books" and to the gliding planes which destroy or decrease greatly the value of the sheets.

Graphite.—Traces of graphite have been found near Pylesville in Harford County at the edge of the Peachbottom slate belt. Several deposits occur farther northward in Pennsylvania where they have been mined to some extent.

Barytes.—Lens-shaped bodies of barytes have been found in Frederick and Carroll counties. They probably occur as fillings of irregularly-formed fissures but the extent and character of the deposits have never furnished evidence of much commercial value.

Talc, Soapstone, and Asbestos.—Small deposits of soapstone, talc, and asbestos are found associated with the different serpentine bodies scattered through the Piedmont region. The massive varieties of talc included under the term soapstone have been quarried at irregular intervals from an extensive deposit found northwest of Marriottsville in Carroll County and from less extensive deposits in Cecil, Harford, and Montgomery counties. A small amount of the output is sawn into slabs for sinks, tubs, fire-brick, and hearth-stones, but most of the product is ground and sold to the manufacturers of acid-proof and fire-proof paints. The higher grades of talc demanded for medicinal purposes have not been found within the State in quantities large enough for successful mining.

Asbestos, or more properly chrysotile, since it is not true asbestos but the fibrous variety of serpentine, has been found at several places within the State. The deposits, however, are small and the quality inferior. When ground the fibers obtained are short and brittle and the rock is too thoroughly impregnated with the silica to make its manufacture a profitable venture. Prior to the discovery of better deposits elsewhere, especially in Canada, there were quarries in Harford and Baltimore counties, but these have long since been abandoned.

The present production of talc and soapstone is sold by the short ton, being worth about $4 a ton in the rough, $25 sawn in slabs, and $7.50 ground. The values vary within wide limits, depending upon the market, the location of the works, and the size of operations of the producers.

LIST OF TALC AND SOAPSTONE OPERATORS.

OPERATOR.	OFFICE.	QUARRY.
Deland Mining & Milling Co	Havre de Grace	Bald Friar.
Thomas & Son	Westminster	Westminster.
The Steatite Corporation	Baltimore	Marriottsville.
Cecil Mineral Company	"	Rock Springs.

MARYLAND COAL OPERATIONS

IN 1907

The State Geological Survey made a detailed examination of the Maryland coal mines five years ago in the preparation of its Report on the Coals of Maryland. Mr. N. Allen Stockton prepared at that time a valuable article, in which he described the condition of the mines, but with the great changes which have taken place in the coal industry in the last few years, brought about by the development of the "Small Veins," it seems desirable to present a revised statement regarding the several operations. The various companies have been communicated with, and Dr. J. J. Rutledge, a representative of the Survey, has visited the district for the purpose of securing additional information. The statements herewith presented have been carefully revised, in most instances by responsible officials of the companies whose mines are described, and they are as nearly accurate as they can well be made. A list of the various coal operators will be found on pages 107-108.

ALLEGANY COUNTY.

THE CONSOLIDATION COAL COMPANY.*

The Consolidation Coal Company operates the following mines in the Georges Creek region: Ocean No. 1 at Ocean, Ocean No. 3 at Hoffman, Ocean No. 3½ at Eckhart, Ocean No. 7 at Lord, Ocean No. 8 at Midland, Tyson No. 7 at Lord, Tyson No. 8 at Midland, and Tyson No. 9 at Frostburg. These mines extend from the northern end of the town of Frostburg to Midland, and occupy the greater part of the northern half of the Georges Creek coal basin.

Ocean No. 1.—The plant and opening of Ocean mine No. 1 of the Consolidation Coal Company at Ocean Station on the Cumberland and Pennsylvania Railroad, lie a mile to the east of the center of the coal basin. The mine is entered by a slope and the coal from a large area of

* For location of the mines see Report on the Coals of Maryland, Pl. XXXII. Also Md. Geol. Survey, Vol. V, 1905.

"Big Vein" lying in the center of the basin is brought to the surface through this opening. The average thickness of coal of this mine is about 9 feet. The workings extend to the northeast nearly to the workings of the old Borden shaft. They join Ocean No. 7 to the west, the Georges Creek Coal and Iron Company's mines No. 1 and No. 4 on the south, and Ocean No. 8 on the southeast and east.

About 682 men were employed and 34 mules used in the underground operations of this mine in 1907, the maximum daily output of the mine for that year being about 2000 tons. The loaded mine cars in

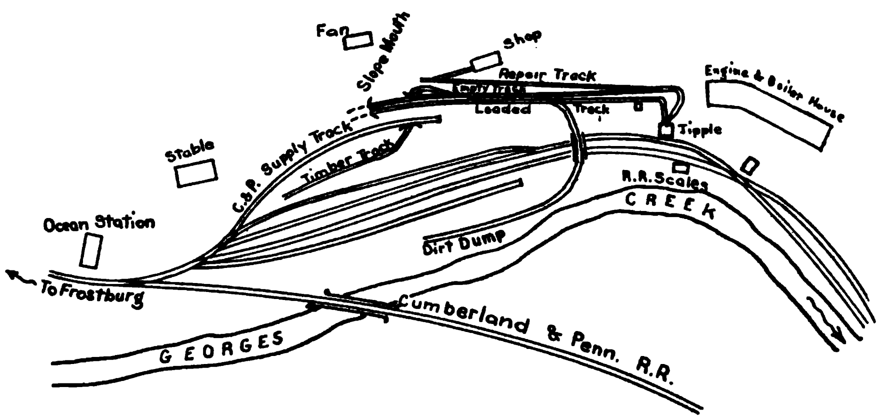


FIG. 2.—Sketch of Track Arrangement at Ocean No. 1, Consolidation Coal Company.

"trips" of 27 cars are hauled up a single-track incline to the surface and landed close to the tipple by an 18 x 36-inch double cylinder geared engine which operates a drum 3 x 8 feet. The drum winds a haulage rope $1\frac{1}{8}$ inch in diameter which pulls the "trip" up the incline. A full day's work at Ocean No. 1 consists of 31 "trips" of 27 cars each. The grade of the inclined plane at the mouth of the mine is 12 feet in 100 feet and is steep enough for the empty "trip" going in to pull the haulage rope with it.

From the slope, the empty cars are taken by compressed air locomotives and distributed to the room headings. There are two air-motors, weighing 16 tons each, one weighing 10 tons, and three weighing 4 tons each.

These locomotives are supplied with compressed air by a three-stage Ingersoll-Sergeant compressor situated on the surface. The compressed air at a pressure of 850 pounds per square inch is forced into the mine through pipes and the locomotives are charged from this pipe-line. One Ingersoll-Sergeant, three Harrison, and five Sullivan coal-mining machines were working in this mine in 1907, the power used to operate them being compressed air, which is supplied through pipes at a pressure of about 80 pounds to the square inch by a duplex Corliss air compressor 16 x 18½ x 36 inches stationed in the main power house on the surface. This air compressor also furnishes power to work one Jeanesville pump 16 x 30 x 14 x 48 inches, one Jeanesville pump 7 x 10 x 24 inches, one Jeanesville pump 14 x 14 x 36 inches, one Hall pump 10 x 14 x 24 inches, all located within the mine. The plant includes a reserve straight line compressor 26 x 24 x 30 inches for emergencies, and four smaller pumps at different points in the mine.

The ventilation of this mine as well as that of Ocean No. 8 is accomplished by a direct-connected Guibal fan with spiral casing. This fan has a diameter of 25 feet. A battery of nine return-tubular boilers (which are 80 horse-power each) supplies steam at a pressure of 100 pounds to the square inch to the slope engine, the air compressor which charges the mine locomotives, the air compressor which supplies air to the pumps and mining machines, and the fan.

There is also in operation at this mine, a 16″ x 14″ Harrisburg engine, directly connected to a 110 K. W. generator, for supplying light to the town of Midland.

The coal is worked in this mine, as in nearly all of the mines of the Consolidation Coal Company, by the room and pillar system. A pillar of coal 40 to 50 feet thick is usually left between the parallel entries and the rooms are driven 12 to 14 feet wide, the point lines of the rooms being usually 55 to 100 feet apart so that a pillar of coal about 40 to 85 feet thick supports the rooms until the pillars are drawn. The length of rooms or the distance between each set of parallel side entries is usually from 400 to 500 feet. The mine cars used at Ocean No. 1 as well as Ocean No. 7 have a capacity of 5400 pounds of coal and weigh 1700

pounds when empty. The gauge of mine-car track is 3 feet. The mine is mainly drained by the water tunnel which empties into Georges Creek three-fourths of a mile below the mouth of Ocean No. 1 and close to the entrance to the drift of Ocean No. 8.

Ocean No. 3, known also as the Hoffman mine of the Consolidation Coal Company, has its tipple on the end of the Eckhart branch of the Cumberland and Pennsylvania Railroad, a mile south of the Eckhart mine and like the latter is a slope on the eastern outcrop of the "Big Vein." Five hundred and twenty-three men and 27 mules were used in the operation of this mine in 1907 and the maximum daily output from the slope workings was about 1300 tons of coal. A duplex stationary engine geared to a drum 6 feet in diameter winds a wire rope, which pulls the loaded mine cars up the slope and lands them on the surface. The empty cars return into the mine by gravity, pulling the rope in with them to the foot of the slope. One compressed-air motor weighing 30,000 pounds, brings the loaded cars to the foot of the slope and distributes the empties into the headings. Four compressed-air motors weighing 1000 pounds each gather the cars in the rooms. The motors are supplied with air from the high-pressure compressor located at the Pumping Shaft. A number of local sumps are drained by pumps driven by compressed air. All the water of the mine flows through the Hoffman Drainage Tunnel, two miles in length, which has its western end near the bottom of the slope, and its eastern, or discharge-end, near Clarysville. A direct-connected Guibal fan 20 feet in diameter constructed for either compressed or exhaustive ventilation furnishes it with air. Four return-tubular boilers, two of 80 horse-power and two of 60 horse-power, supply steam to the fan and stationary engine.

The usual pillar and room system is employed in this mine for working the coal. Rooms are driven 12 to 14 feet wide. In the newer working of the mine the centers of the rooms are usually 100 feet apart, and 300 to 400 feet is left between each pair of parallel headings. In the older workings the rooms were driven with 35 feet between centers and the intervals between headings were greater. The coal is 9 feet thick and is mined by pick-work and machines. There are two Sullivan, one

AN AND PROFILE

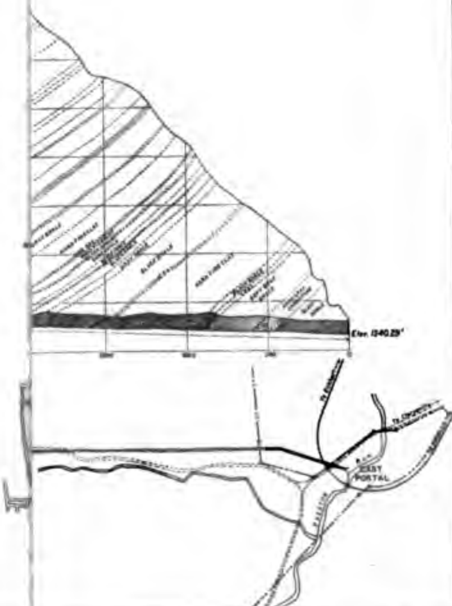
OF THE

DRAINAGE TUNNEL

AN No 3 MINE

SOLIDATION COAL CO.

DEP'T., H. V. HESSE, Chief Engr.



Harrison and two Ingersoll-Sergeant mining machines in operation. The mine cars are loaded to contain 5400 pounds of coal and weigh 1700 pounds when empty. The gauge of tracks is 3 feet. The tipple consists of a balance cradle, the framework supporting it being of wood. A short tramway connects the mouth of the slope with the tipple.

There is also operated at Ocean No. 3, a drift opening known as Hoffman Drift mine, following the outcrop of the "Big Vein" from a point near the mouth of the slope, southward toward Vale Summit.

Three openings have also been made at Vale Summit just north of the Georges Creek and Cumberland Railroad depot. One is a slope driving in a southwesterly direction and the other two are drift openings driving in a southeasterly direction. Coal is hauled up the slope by a small stationary engine, while a 12-foot Crawford and McCrimmon fan furnishes air. A 48-horse-power return tubular boiler supplies steam to the engine and fan. The ventilation of the drift opening is natural.

A small steam locomotive hauls the coal from the openings to Ocean No. 3 over a tram-road two miles in length. Connection with Hoffman Drift mine is also made near Vale Summit and some of the coal brought to the tipple on the tram-road. The daily output from these openings is about 325 tons, all of which is loaded over Ocean No. 3 tipple.

Pumping Shaft.—In addition to the numerous mines it operates, the Consolidation Coal Company maintains a power plant at a shaft located at very nearly the axis of the basin, a mile and a half west of the mouth of Ocean No. 3 slope. The shaft is sunk to the "Big Vein," and is about 250 feet deep.

This power plant was formerly maintained for pumping water from Ocean No. 3 mine and furnishing power for the compressed air locomotives used in the mine. Since the completion of the Hoffman Drainage Tunnel, no water is pumped from the shaft. In addition to compressed air for haulage and mining machines, power is now furnished a number of pumps pumping from local basins in Ocean No. 3 mine.

The equipment of the plant consists of a small geared engine for hoisting the cage in the shaft, one three-stage compound Norwalk air-compressor, and a duplex Corliss air compressor.

Coal is obtained from an opening in the Waynesburg seam just south of the boiler house. Coal was formerly mined from the lower Sewickley seam in the shaft. The plant has eight boilers of 80 horse-power each.

Ocean No. 3½.—At Eckhart, a mile and a half east of Frostburg, the Consolidation Coal Company operates its Ocean mine No. 3½, a slope on the eastern outcrop of the "Big Vein." One hundred and seventy-eight men are employed, seven mules are used, and the daily output of the mine is 440 tons. A 16 x 24-inch double cylinder geared engine with a drum 6 feet in diameter and 3 feet wide pulls the loaded mine cars up an incline to the surface and drops the empty cars back into the mine. A tram road connects the opening of the mine with the tipple on the Eckhart branch of the Cumberland and Pennsylvania Railroad. The mine is supplied with air by a Guibal fan 16 feet in diameter with belt connection, constructed for either exhaustive or compressive ventilation. The haulage engine and fan are supplied with steam by two return-tubular boilers 15 feet long and 54 inches in diameter of 70 horse-power each. One return-tubular boiler 18 feet long and 72″ in diameter of 150 horse-power supplies the electric generator-engine with steam. No coal-mining machines are used. There are in service at the mine two small electric pumps. The mine is drained by the Allegany Water Ditch and Hoffman Tunnel.

The mine is equipped with electric haulage. A 100 K. W. generator, driven by a 15″ x 21″ belt-connected four-valve Erie engine furnishes power for the 10-ton electric motor.

Ocean No. 7.—Ocean mine No. 7 of the Consolidation Coal Company is situated at the head of Wright's Run on a branch of the Cumberland and Pennsylvania Railroad about halfway between Frostburg and Lonaconing and a mile west of the center of the Georges Creek coal basin. The coal is mined from the "Big Vein," which in this mine is about 9 feet thick. In 1907 about 1125 men were employed at this mine and 70 mules were used in the inside work. Five thousand seven hundred and eight long tons of coal have been loaded at this mine in one day. The coal is taken from each side of the narrow valley or ravine in which the tipple and tracks are located. On the northwest side of the valley the coal

is mined to the rise, mules hauling the empty cars into the mine through one entry and the loaded coal cars running out to the tipple through another entry by gravity. The "Big Vein" coal that lies between these openings and the outcrop of the western edge of the coal basin is brought to the surface through these drifts. The main opening of this plant, however, is on the southwest side of the ravine and through it a large area of coal that lies to the dip is brought to the tipples. This main opening is made secure by a substantial brick arch of sufficient diameter

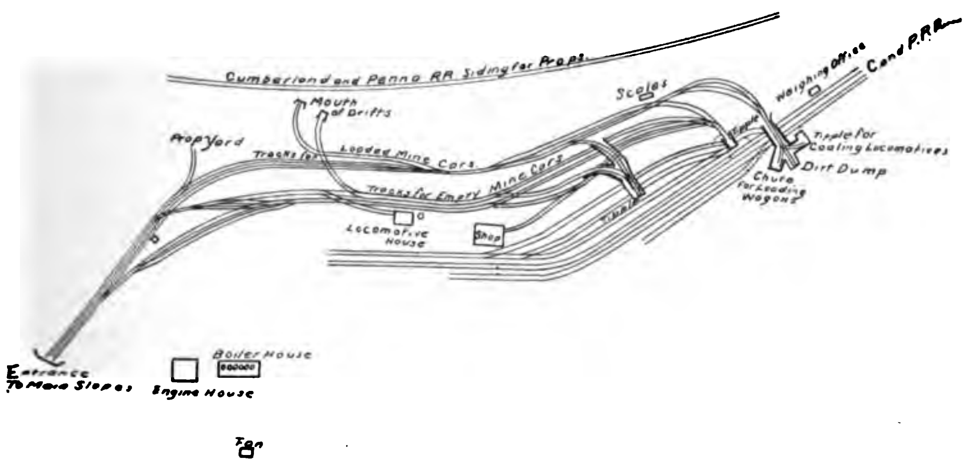


FIG. 3.—Sketch showing Track Arrangement, Ocean No. 7, Consolidation Coal Company.

for two mine car tracks to enter. A short distance inside of the mine the two tracks diverge, one passing under the other, descending in two directions to the south and southeast toward the workings of Ocean No. 1 and the center of the coal basin. The loaded cars are pulled in "trips" of 22 cars up the least steep of these slopes or inside incline planes and landed just outside of the mouth of the mine, by an engine located on the surface operating a double drum and winding a 1½-inch pulling rope. From the mouth of the mine the loaded cars run by gravity to the tipples. From the tipples the empty mine cars return towards the mine by gravity as far as they will run and then are taken in "trips" of 22 cars by a tail-

rope up the grade to the mouth of the mine where another tail-rope is attached and the "trip" of cars is pulled into the mine a short distance to a point where the grade is sufficiently heavy for the empty trip to take the pulling rope in with it. From the different headings off the slope the cars are taken by drivers with mules and distributed to the rooms. The loaded mine cars are brought up the steeper of the two inside slopes in "trips" of 24 to 26 cars and landed on the surface by a 26" x 48"

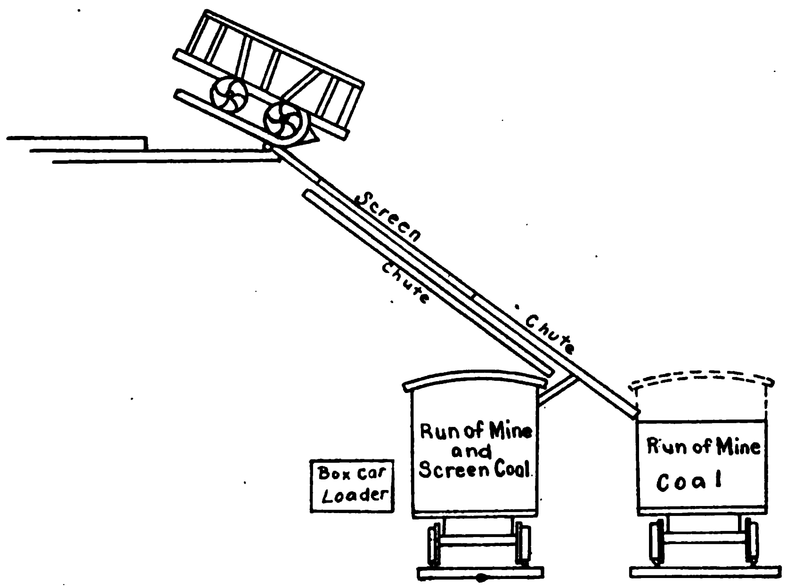


FIG. 4.—Sketch showing Main Tipple, Ocean No. 7, Consolidation Coal Company.

stationary engine operating a drum and winding a 1⅛-inch rope. These loads run by gravity to the tipples. From the tipples they are returned to the mines in the same manner as the cars from the other slope. The grade of both the inside slopes is sufficiently heavy for the empty cars going down the slope to take the pulling rope in with them and a tail-rope is therefore only necessary to pull the empty cars into the drift to the head of the slopes.

For ventilating the workings of Ocean No. 7 two direct-connected fans of the Guibal pattern with spiral casings are used, one having a

diameter of 12 feet and the other 25 feet. They are constructed so that they can be used for either exhaustive or compressive ventilation. Steam is supplied to the stationary engines and fans by 10 return-tubular boilers, four of 100 horse-power each, three of 150 horse-power each, and three of 80 horse-power each. The mine is self-draining through the water-level drainage tunnel that runs through the center of the coal basin and empties into Georges Creek below the mouth of Ocean No. 8 at Midland.

The coal from Ocean No. 7 is dumped into the railroad cars on the branch of the Cumberland and Pennsylvania Railroad over two tipples, in addition to which the plant has a tipple for supplying locomotives with

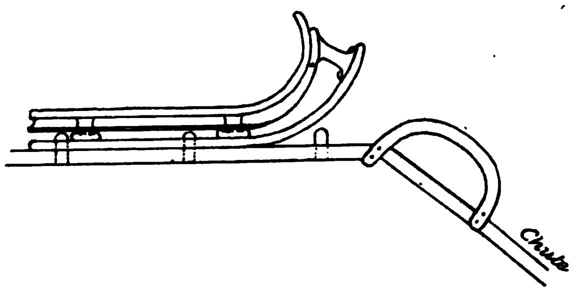


FIG. 5.—Sketch showing Rocker for Dumping Coal used by Consolidation Coal Company.

fuel. Both tipples are constructed to screen the coal and load the lump and the slack at the same time.

The chutes of these tipples are also furnished with folding steel iron flaps or doors which shut down and cover the screen when run of mine coal is to be loaded. When the screens are covered run-of-mine coal can be loaded into cars on either of the railroad tracks shown in the sketch.

Both tipples are equipped with box car loaders of the Ottumwa type.

The tipples of this plant are of the rocker pattern, designed by Mr. B. S. Randolph, which is very simple in construction and effective in its action. The T-rails are bolted to two flat strap iron "rockers." As the car is run onto the tipple and strikes the horns, its momentum tips the rockers toward the chutes. The end gate of the mine car being latched by a lever projecting beyond the side of the car, the lever strikes an iron

loop bolted to the side of the tipple. The end gate is unlatched and opens, allowing the coal to fall into the chute. The rocker is kept in place by iron pins in the frame work underneath the rockers which fit into slots or notches in the rocker. The chute over which the run of

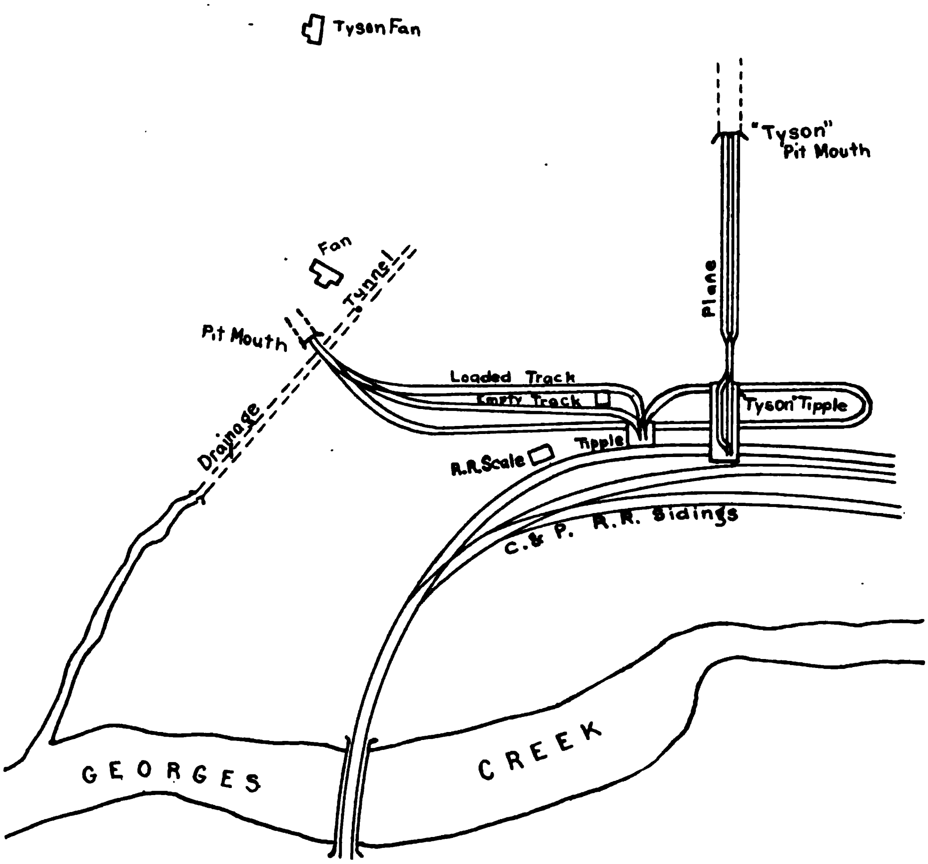


FIG. 6.—Sketch of Track Arrangement, Ocean No. 8, Consolidation Coal Company.

mine coal is mainly loaded is sprinkled with water from a pipe above to induce the coal to slide in it more freely.

The coal in Ocean No. 7 is mined both by pick and coal-mining machines. Twenty-two machines were in use in this mine during the past year, all of them being of the "puncher" type Ingersoll-Sergeant

mining machines. Compressed air is supplied by three compressors, one Rand compressor 12″ x 16″, one Rand compressor 14″ x 22″, and one Ingersoll-Sergeant compressor, 14″ x 18″. Mine cars are of the pattern common to the Consolidation Coal Company, and the gauge of the mine tracks, as in all the plants of this company, is 3 feet. The rooms are usually driven in Ocean No. 7 with centers 65 feet apart.

Ocean No. 8 of the Consolidation Coal Company has its tipple on a siding of the Cumberland and Pennsylvania Railroad on the west side of Georges Creek close to Midland station, the workings of this mine adjoining those of Ocean No. 1 and No. 4 of the Georges Creek Coal and Iron Company. The mouth of this mine is about three-fourths of a mile east of the middle of the coal basin and the main heading, driven southwest nearly on the strike, takes out the coal that lies to the rise toward the east between it and the out-crop line formed by the erosion of the waters of Georges Creek. An area of coal adjoining this mine also on the east was formerly operated at this point by the Big Vein Coal Company. The present mine was opened and operated by the Consolidation Coal Company in May, 1902; the daily output is about 200 tons. Seventy-nine men were employed during 1907 and seven mules haul the coal from the mine to the tipple and haul the empty cars into the mine.

The mine is ventilated by a direct-connected Guibal fan, 15 feet in diameter. Steam is supplied from a 60-horse-power return-tubular boiler.

The mine water flows out through the workings of Ocean No. 1 into the main drainage tunnel which has its outlet to Georges Creek almost immediately underneath the entrance to the mine. The drainage tunnel was driven from Georges Creek at Midland about 900 feet through rock to tap and drain the "Big Vein" at the bottom of the coal basin. From the point where the drainage tunnel taps the "Big Vein" a water-level heading was driven through the basin and this heading now drains the Georges Creek Coal and Iron Company's mine No. 1 as well as Ocean Nos. 7 and 8 and the upper workings of Ocean No. 1.

Tyson No. 7.—The Consolidation Coal Company operates three mines

in the Tyson seam which covers a wide area on the company's properties. Tyson No. 7 is located near Ocean No. 7, the coal being mined to supply the boilers of the latter plant. The coal is hauled by mules from the mine to the boiler house. Nine men were employed on the average during 1907 and two mules were used. The ventilation is natural. The output is about 30 tons daily.

Tyson No. 8.—Tyson No. 8 mine of the Consolidation Coal Company has its opening at Midland near the Ocean No. 8 "Big Vein" opening, the same railroad siding being used for both mines. The loaded cars are brought to the tipple down a steep gravity plane. Thirty-one men were employed during 1907 and four mules used. The output is about 50 tons a day.

Ventilation is furnished by a 12-foot fan of the Guibal pattern supplied with steam from Ocean No. 8 plant, and the mine is drained through bore holes driven to the "Big Vein."

Tyson No. 9.—At the upper end of the Y of the Cumberland and Pennsylvania Railroad, about a mile and a half northeast of Frostburg, the Consolidation Coal Company operates a mine in the Upper Sewickley or Tyson seam. The locomotives of the Cumberland and Pennsylvania Railroad are coaled here and shipments also made. There are two tipples, one for coaling locomotives and the other for loading cars. The former is on the main line of the Cumberland and Pennsylvania Railroad, while the latter is a little south on a siding.

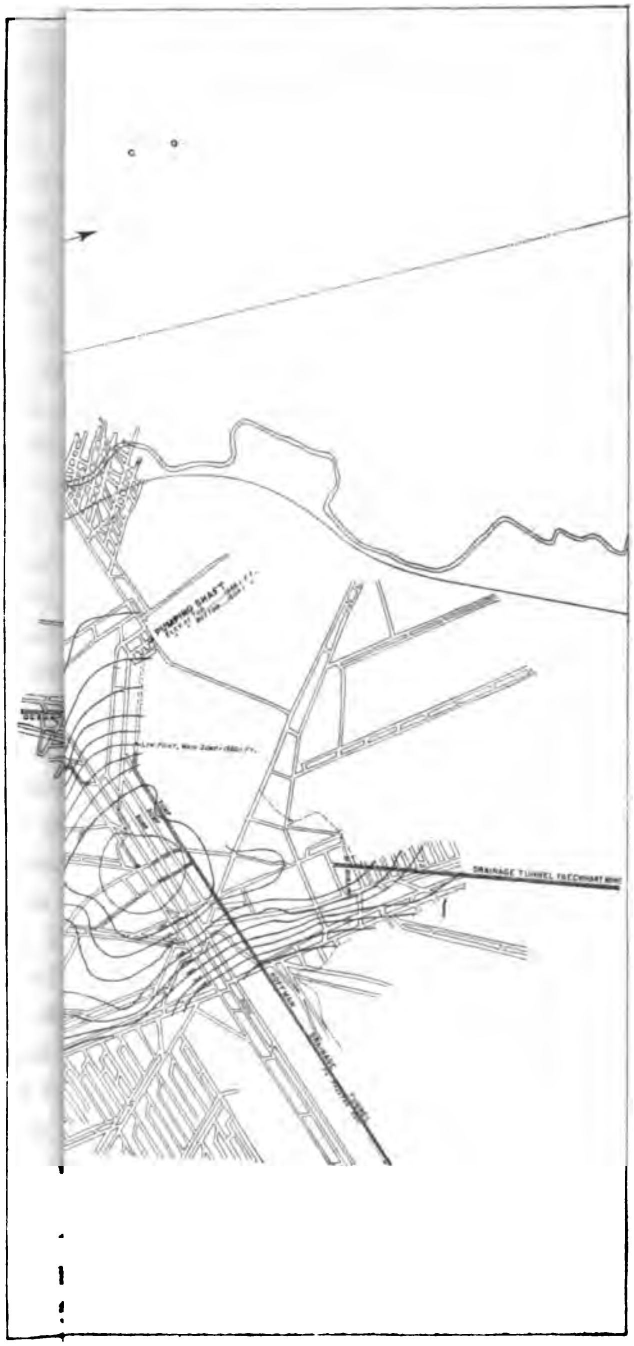
The mine has three openings, the coal from the most northern being used for coaling locomotives, while coal from the other two openings is shipped.

Ventilation is furnished by a fan 12 feet in diameter. Steam is supplied by a boiler of 20 horse-power. About 66 men were employed during 1907 and nine mules used. The output is 150 tons per day.

Drainage System of Mines.—The Hoffman Drainage Tunnel is an adit driven in the Conemaugh formation, from Preston Run, about one-half mile from the junction of that stream with Braddock Run, to the lowest point of the Georges Creek "Big Vein" workings.

Its length is 10,679 feet, or 2.02 miles, its grade 0.355%, or 4½ inches

 PLATE XI.



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per 100 feet, its direction North 76° 21′ East, and it is 8 feet wide and 7 feet high in the clear. Although it is sufficiently wide to be used as a haulway, it is devoted entirely to drainage.

Its western portal, or entrance, having a tidal elevation of 1584.1 feet, is located near the foot of the main slope of Ocean No. 3 mine (known locally as Hoffman mine), and its eastern portal, or outlet, on Preston Run, has a tidal elevation of 1540.29 feet, the total fall being approximately 44 feet.

Work was commenced in November, 1903, and prosecuted continuously until its completion in August, 1906. It was attacked from four headings, driving from the two portals and in both directions from a shaft near the center, sunk from the Ocean No. 3 mine-workings to grade at a depth of 180¾ feet.

During the progress of the work fifteen coal seams, varying from 2 inches to 4 feet 8 inches in thickness, were encountered, the most important being the Franklin, or Little Clarksburg, and the Barton, or Bakerstown. In addition to these, two small seams of iron ore and four beds of hard fire clay were passed through.

The immediate result of the completion of this tunnel was the elimination of an expensive pumping station located at the bottom of a 250-foot pumping shaft.

Its prime object is the unwatering of the mine workings of the Consolidation Coal Company, but before this can be accomplished in its entirety, a series of auxiliary rock ditches and tunnels are necessary on account of the rolling nature of the measures. There will be 12,000 feet of open rock ditches with a maximum cut of 16 feet and 4150 feet of additional tunnels. These auxiliary ditches and tunnels are now in the course of construction and it is expected to complete them within the next two years.

There are in operation now, in addition to the Hoffman Drainage Tunnel, 17,000 feet of rock ditches and about 1000 feet of tunnel, which were driven some years ago. The completed system will include 29,000 feet of rock ditches and 16,800 feet of rock tunnels, or a total length of 8⅔ miles of drainway.

BLACK-SHERIDAN-WILSON COMPANY, AGENTS.

The Union Mining Company, the New York Mining Company, the Barton and Georges Creek Valley Coal Company, and the Potomac Coal Company, for all of which the Black-Sheridan-Wilson Company are the selling agents, operate the following mines: the Union mine, just north of Frostburg; the Union mine No. 1, about one mile north of Frostburg; the Union mine No. 2, about one mile north of Frostburg; the Carlos mine, near Carlos, and the Potomac mine, near Barton.

With the exception of Potomac mine, which is mining the Bakerstown or "4-foot" seam, all the mines mentioned above are working exclusively the "Big Vein," The New York Mining Company has commenced the development of the Tyson seam above Union mine No. 2 and is already shipping a small amount of coal. The daily capacity of all the operations exceeds 3000 tons.

Union mine.—The plant of Union mine, operated and owned by the Union Mining Company, is situated on a siding of the Cumberland and Pennsylvania Railroad, at the head of the valley of Jennings Run, near the northern limits of Frostburg. The company is not only removing the coal from its own property, but also from the adjacent territory owned by the Consolidation Company.

There were 150 men employed in 1907. The daily capacity is 600 tons. New territory is being opened up, and the tonnage will be gradually increased.

The coal is mined exclusively by hand, no machines being used or blasting of coal permitted. It is loaded into mine cars the capacity of which is 3½ gross tons, and hauled by tandem team to daylight, where it is loaded in railroad cars either as a run-of-mine coal, or screened and prepared for special use, such as blacksmithing.

The mine is self-draining, and ample ventilation is furnished by a 16-foot Crawford & McCrimmon fan.

Recently the company has taken a lease on the New Hope mine, near Frostburg, which has not been operated for 17 years.

Union mine No. 1.—This mine is owned and operated by the New York Mining Company, and is situated on the west side of the valley of

Jennings Run. It is reached by a spur of the Cumberland and Pennsylvania Railroad, which leaves the main line at Allegany.

Ground was broken for this operation during the spring of 1906 and shipment of coal began in December, 1906. Development-work only is being prosecuted, the mining being confined to headings and their air courses. Its present capacity is 500 tons, but when fully developed it will have an output of 1200 tons daily.

Arrangements are being made for electric haulage, the power for which will be furnished by the generating plant of Union mine No. 2, which is situated directly across the valley.

The tipple designed by the Jeffrey Manufacturing Company is quite elaborate, special attention being given to the economical cleaning and handling of coal and refuse.

A Sullivan cross-over dump is used, which empties the coal into a weigh-box of 6 tons capacity; the coal is then discharged to a feed conveyor, which regulates the depth of coal on the picking-table; from the picking-table the coal runs into railroad cars either as run-of-mine coal, lump, or fine. Conveyors for handling refuse are also employed. The picking-table and conveyors are operated by electric motors.

A 12-foot ventilating fan is used, and no pumps are required. Sixty men on the average were employed during 1907.

Union mine No. 2—also owned and operated by the New York Mining Company—is situated on the east side of Jennings Run Valley, directly opposite Union No. 1, and is reached by a switchback from the Cumberland and Pennsylvania Railroad.

This mine has been in operation since 1894 and has a present capacity of 1500 tons.

As at the other mines, no machines are employed, all the mining being done by hand. The coal is hauled to the main heading by horses, thence to the tipple by electric motors. The power plant has a normal capacity of 400 horse-power; this is now being increased so as to furnish power for Union mine No. 1. There were 450 men employed on the average during 1907.

Ventilation is furnished by two fans of 16 and 12 feet in diameter. Over 400 men are employed.

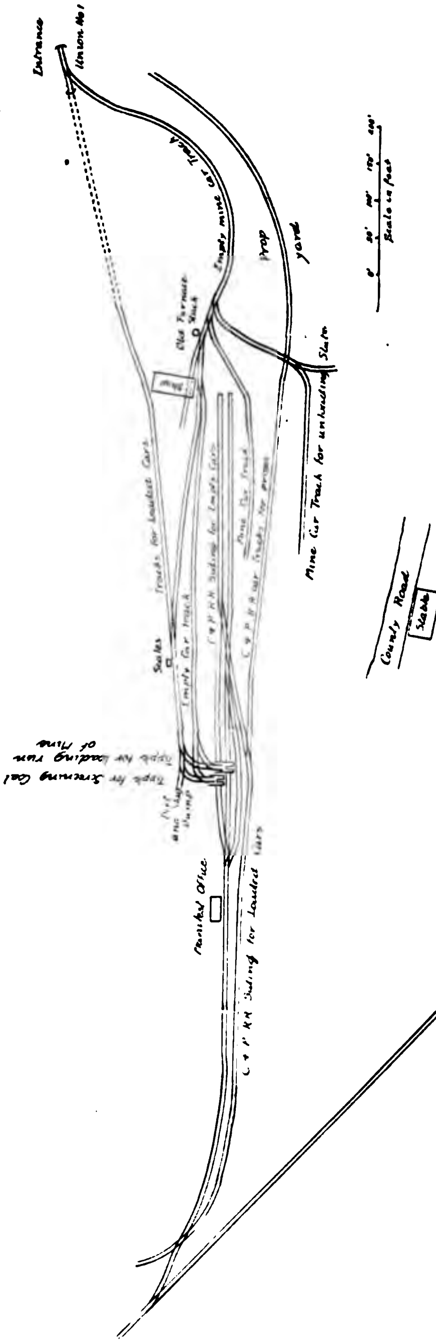

FIG. 7.—Sketch showing Track Arrangement, Union Mine No. 1, Union Mining Company.

The company has also opened up the Tyson seam, just above Union No. 2, and already 10 to 12 men are engaged in the operation. When a mechanical system of ventilation is installed a large amount of high grade coal can be mined from this seam.

Carlos mine—operated by the Barton and Georges Creek Valley Coal Company—is situated at the end of the Carlos branch of the Cumberland and Pennsylvania Railroad, about two miles southwest of Frostburg.

The capacity is 900 tons daily, and about 209 men were employed during 1907.

The coal lies below water-level, and is brought to the surface through a slope 2400 feet long, the grade of which averages 10 feet to the hundred. A double 14″ x 18″ haulage-engine is used, handling about 50 tons per trip.

Two-stage centrifugal pumps, of a total capacity of 1000 gallons per minute, were used to handle the water, but now natural drainage is afforded by the water-tunnel of the Consolidation Coal Company.

Two 150-horse-power return-tubular boilers furnish steam for haulage-engine, ventilating-engines, etc. No mining machines are used.

Potomac mine.—This mine is owned and operated by the Potomac Coal Company, and is situated about one mile southeast of the town of Barton.

As the mine opening is somewhat over one mile from the Cumberland and Pennsylvania Railroad, a steam locomotive is used on the 4-foot gauge tram-road that connects the mine with the railroad. Tram-cars of 3 tons capacity are used.

The Bakerstown or "4-foot" is the seam of coal worked, which at this point shows an average thickness of 30 inches of clean coal.

The "room and pillar" method of mining is used; rooms driven 30 and 40 feet wide, while the pillars never exceed 20 feet in thickness. Top is taken down in the headings to give height for the small mules that are used to haul the coal.

The mine cars have a capacity of 1500 pounds. Ventilation is furnished by a 20-foot fan, and the drainage is natural. The capacity of the mine is 300 tons daily, and about 74 men were employed during 1907.

THE GEORGES CREEK COAL AND IRON COMPANY.

The Georges Creek Coal and Iron Company now operate four drift mines in the Pittsburg seam or "Big Vein" and have lately opened two mines in the Upper Sewickley or "Tyson" seam. The "Big Vein" mines operated are mine No. 1, a mile north of Lonaconing; mine No. 12, two miles northeast of Lonaconing; mine No. 13, on east side of valley, above Lonaconing, and mine No. 14, on west side of valley, one and one-half miles from Lonaconing. The Tyson mines are No. 16 and No. 17.

Mine No. 1 of the Georges Creek Coal and Iron Company lies on the west side of the Georges Creek valley, three-fourths of a mile north of the corporate limits of the town of Lonaconing. No. 1 mine has connections with and tipples on both the Cumberland and Pennsylvania and the west branch of the Georges Creek and Cumberland Railroad. In 1907 130 men were employed. The coal is brought from the interior of the mine to the surface by a double tail-rope system operated by a stationary engine on the surface having four drums 6 feet in diameter and 3 feet wide and winding a ⅞-inch hemp-center steel-wire rope. The engine is supplied by a 150-horse-power return-tubular boiler. At the mouth of the mines the tail-rope is disconnected and the loaded cars run themselves by gravity down an 8% grade to a landing near the tipple on the Cumberland and Pennsylvania Railroad, whence they are run by hand into the tipple. The empty cars, after being dumped, run from the tipple by gravity back toward the mine. The track on which they return is long enough to hold 30 empty cars at a time. This track is constructed with a sufficient grade so that the front car of each "trip" of 30 empty cars to be pulled into the mine will run to the place where the main pulling rope disconnected from the "trip" of loaded cars can be attached to it.

When mine cars from mine No. 1 are to be run to the tipple on the Georges Creek and Cumberland Railroad the tail-rope is disconnected from the front end of the "trip" of loaded cars when it reaches the mouth of the mine and in place of it one end of a "cut-off" rope or long link is attached to the front end of the "trip." The "cut-off" rope passes out the center of the track to a "bull wheel" near the tipple, around this

wheel and returns along the side of the track to the mouth of the mine. The tail-rope, which is disconnected from the "trip," is attached to the other end of the "cut-off" rope, and the tail-rope then pulls the "trip" of cars to the tipple on the Georges Creek and Cumberland Railroad, taking the pulling-rope, which is still attached to the other end of the "trip," with it. When the "trip" of empty cars is brought back to the mouth of the mine by the pulling-rope, both ends of the "cut-off" rope are brought back to the mouth of the mine where it is disconnected from

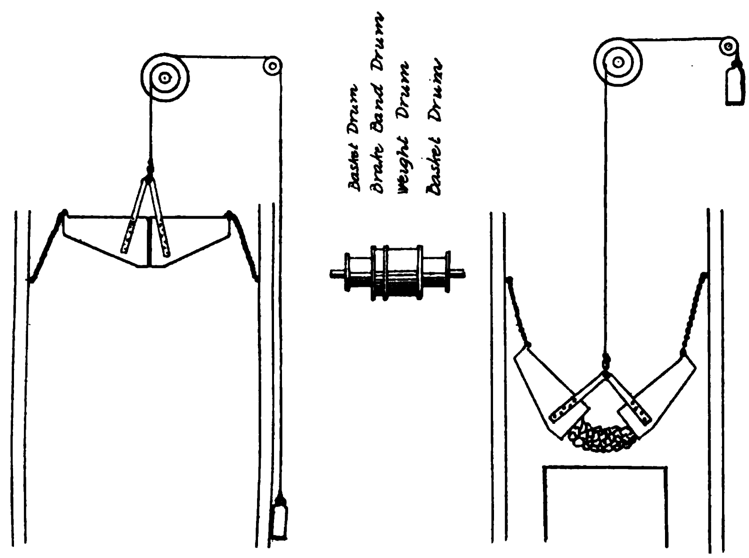

FIG. 8.—Sketch of Basket employed in Loading Cars by Georges Creek Coal and Iron Company.

the "trip" and tail-rope and the latter is replaced on the hind end of the "trip" going into the mine. The "cut-off" rope is thus left in position for connecting into the haulage system when needed. The main tipple of mine No. 1 on the Cumberland and Pennsylvania Railroad is a Mitchell tipple with an iron basket attachment. The coal is first dumped into the basket and then the basket containing the coal is lowered into the railroad cars, the main object of the basket being to prevent breakage of the coal and therefore obtain a greater percentage of lump coal. The basket is suspended by a wire rope wound around a drum. The weight of the

coal from a mine car dumped into the iron basket causes the basket to descend, the drum is turned and another wire rope with a weight attached is wound upon a drum of larger diameter on the same shaft as the smaller drum. When the basket has been lowered to the desired height it is opened by chains which connect it with the framework of the tipple. When the coal is emptied from the basket the weights attached to the rope of the larger drum wind the basket rope upon the smaller drum again and lift the basket up to the level of the floor of the tipple. The basket is controlled by a brake band on the larger drum which is operated by a lever. In addition to the Mitchell tipple the dump has also a chute for loading box cars. On the Georges Creek and Cumberland Railroad the tipple for loading the coal from mine No. 1 is of the ordinary frame back-balance pattern.

The entrance to mine No. 1 is very nearly at the center of the coal basin. It reaches the coal that lies on the western slope of the basin and is self-draining, while old No. 4, nearby, and not now worked, is in that part of the "Big Vein" coal lying in the center of the basin and on its eastern slope. The grades in the latter mine are very irregular even on the general line of strike of the coal basin where one would expect to find a nearly uniform water-level grade. Mine No. 4 is partly drained by a connection with the Consolidation Coal Company's drainage tunnel and at present no pumps are needed for draining either of these mines.

Two fans of Guibal pattern of 12 and 20 feet diameter respectively furnish exhaustive ventilation to mine No. 1. The fans are supplied by steam from the same boiler that supplies the stationary haulage engines. The gauge of the mine-car tracks used at these two mines is 3 feet and the cars weigh 1800 to 2000 pounds when empty and have a capacity of 2¼ tons of coal. No coal-cutting or mining machinery is used here or in any other of this company's mines in the Georges Creek region. The "Big Vein" coal is from 10 to 11 feet thick in these mines.

Mine No. 12 of the Georges Creek Coal and Iron Company is a drift mine in a detached area of the "Big Vein" that lies on the east side of Georges Creek valley near the eastern rim of the coal basin, midway between the old mines Nos. 3 and 9 of the same company. The mine is

connected with the Georges Creek and Cumberland Railroad over which the coal from it is shipped, by a 4-rail gravity plane 2200 feet long. The tipple is of the usual plain chute type common to the region. This mine was opened and coal first shipped from it in 1903.

Mine No. 13.—This mine is on the east side of the Georges Creek valley above the town of Lonaconing, on the Georges Creek and Cumberland Railroad. The capacity is about 140 tons a day, and an average of 35 men were employed in 1907. The "Big Vein" seam is about 10 feet thick, and is mined by drift. The tipple is about 50 feet from the mouth of the mine. The gauge of the mine tracks is 3½ feet. The mine cars weigh from 1800 to 2000 pounds, and when loaded hold 2½ tons of coal. This mine has natural drainage and ventilation. The coal is mined exclusively by pick-work, the usual room and pillar system of mining being used. The rooms are driven 14 feet wide with point lines 40 feet apart. The cover is not great.

Mine No. 14.—This mine is on the west side of the Georges Creek valley about one and one-half miles from Lonaconing, on the Georges Creek and Cumberland Railroad. The capacity is about 75 tons a day, and an average of 20 men were employed in 1907. The "Big Vein" seam is about 10 feet thick, and is mined by drift. The coal at this mine raises very fast—about 9 feet to the 100. The coal is brought to the tipple by horses. The mine has natural drainage and ventilation. The system of mining is the same as mine No. 13.

Mine No. 16 of the Georges Creek Coal and Iron Company is a drift opening in the upper half of the Upper Sewickley, Tyson, or "Three and a half-foot seam" on the hillside just above the opening of the drift of mine No. 1 ("Big Vein"). A retarding conveyor and washing plant for this mine has just been put in operation. The mine was opened in 1903 and the output is as yet limited. The plant of this mine, which has just been built, consists of three 150-horse-power horizontal tubular boilers. A 238-horse-power engine drives an electric generator, which in turn supplies the power for two stationary electric motors, one of which (of 40-horse-power) operates the endless rope of the retarding conveyor,

the other a 30-horse-power motor runs the machinery that washes and elevates the washed coal from the washer to the storage bins.

The coal is brought from mine No. 16 to the tipple by the retarding conveyor 1000 feet long. At the lower end of the conveyor the coal passes over a screen. The lump coal is loaded directly into the railroad cars and the screen coal is transferred by a screw conveyor to the washer. The washed coal is elevated into the storage bins from which it is loaded into cars on a siding of the Cumberland and Pennsylvania Railroad as it is needed for shipment. The electric generator also supplies power for a 4-ton electric motor for haulage in mines No. 16 and No. 17. The mine has been equipped with a 12-foot Guibal fan, which also ventilates mine No. 17. Thirty-five men were employed in 1907.

Mine No. 17 is a drift into the same coal bed as mine No. 16 and its entrance is on the hillside just above the mouth of the old drift of the Georges Creek Coal and Iron Company's "Big Vein" mine No. 4½. A short, steep gravity plane connects the mine with its tipple on the Georges Creek and Cumberland Railroad and a tramway 2200 feet long joins it with the retarding conveyor near mine No. 16. A 4-ton electric motor transfers the coal from the mine to the conveyor over the tramway. The tipples of mines No. 16 and 17 are entirely independent of those used for loading coal from the "Big Vein" mines in their vicinity. A temporary wooden stack is used for ventilation. The interior workings of mines No. 16 and No. 17 will eventually meet and the haulage and ventilating systems of mine No. 16 will be extended into this mine.

A panel system of mining is employed in both mines No. 16 and No. 17. Rooms are driven in sets or panels of ten as the side entries advance. Each panel is separated from the next by a barrier pillar. The pillars between the rooms are drawn as soon as the rooms of each panel are up. After the pillars are drawn the haulage ways are retained by the necks of the rooms and a protecting stump which is left below the return airway of each set of entries.

The mine car tracks of mines No. 16 and No. 17 have a gauge of 42 inches and mine cars weighing 1000 pounds are used. Some of these are

built entirely of iron but the bodies of the larger number of them are wooden.

THE AMERICAN COAL COMPANY OF ALLEGANY COUNTY.

The American Coal Company operates the Jackson mine, near Pekin, and the Caledonia mine at Barton. At both of these plants the "Big Vein" is worked and at each of them one of the smaller seams overlying the "Big Vein" is mined, that at the Jackson mine being the Waynesburg, and that at the Caledonia mine the Upper Sewickley or "Tyson."

The *Jackson mines* of the American Coal Company are situated on the eastern side of the Georges Creek coal basin above Pekin. The main seam

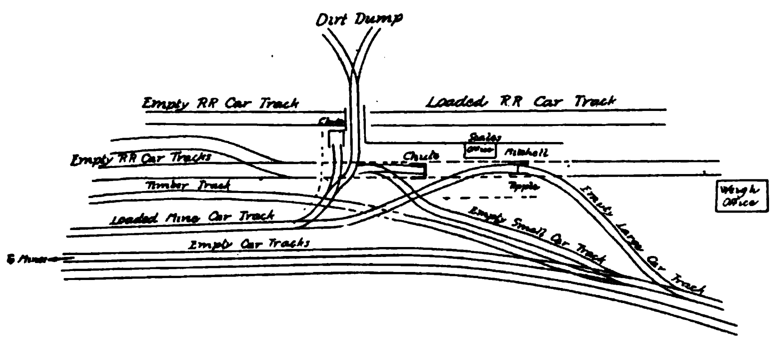

FIG. 9.—Sketch showing Tracks and Three-chute Tipple, Jackson Mine, American Coal Company.

operated is the "Big Vein," which in the mines of this company is from 13 to 14 feet thick. The mine employed in 1907 about 88 men on the average. Two seams of coal lying above the "Big Vein," the "Tyson," and Waynesburg, have also been opened and the coal taken from them now amounts to many tons daily. In the main mine in the "Big Vein" a tail-rope system one mile and five-eighths long brings the coal to the mouth of the drift, whence it is conveyed by a 22-ton locomotive over a tram-road one mile long to the main tipple at Lonaconing. The tail-rope employed consists of two drums 7 feet in diameter winding a $\frac{7}{8}$-inch haulage rope and a $\frac{3}{4}$-inch tail-rope. A Guibal fan 25 feet in diameter with a maximum speed of 90 revolutions per minute furnishes compressive ventilation for the "Big Vein" mine. The tail-rope engine as

well as the fan engine are supplied with steam from two 4½ x 14-feet return-tubular boilers of 100 horse-power each. The mines, like all others now operated in the Georges Creek basin south of Midland, are drifts. The drainage is natural and no pumps are required to dispose of the water. The coal is mined by pick and no mining machinery is used. In the "Big Vein" a mine car is used weighing when empty about 1850 pounds and holding about 2¾ tons of coal when loaded. In the mine in the Waynesburg seam a mine car containing about 1 ton of coal is used. The cars containing coal from the upper vein are let down by a gravity plane to the main tramway. The mine cars of this company differ from those generally used in the region in having a square body projecting over the wheels.

The coal from the mine in the "Big Vein" is mainly dumped through a Mitchell tipple endwise into the cars on the siding of the Georges Creek and Cumberland Railroad. Some of it is, however, loaded sidewise and endwise into the railroad cars over two other plain chutes at the main Lonaconing tipple. The coal from the small vein is loaded into the railroad cars at the same tipple but is only dumped through the plain chutes and not over the Mitchell tipple.

The *Caledonia mines.*—At Barton, four miles southwest of Lonaconing, the American Coal Company operate their Caledonia mines. Both the "Big Vein" and the "Tyson" coal bed lying 110 feet above it are worked by drift openings. The "Big Vein" lies high up on the hill on west side of the Georges Creek valley and coal basin and a gravity plane 2700 feet long connects the main line with the tipple on the Cumberland and Pennsylvania Railroad and another plane 400 feet long lets down the coal from the mine in the "Tyson" seam to the head of the main planes. The coal from both mines is lowered over the main plane and dumped over one tipple. A 1¼-inch wire-rope is used on the longer plane and 1-inch rope on the shorter one. The thickness of the "Big Vein" at the mines is 13 feet 9 inches.

The maximum daily capacity of the "Big Vein" Caledonia mine for 1907 was 500 tons, 70 men and 6 horses being used in the production of the coal. The mine cars used weigh 1820 pounds when empty and con-

tain when loaded $2\frac{3}{4}$ tons of coal. The upper coal seam is about $6\frac{1}{2}$ feet thick.

The greatest daily output of the mine in the "Tyson" coal bed is 150 tons of coal, and 34 men and 2 horses were employed in 1907. The mine cars used in the upper seam are very little smaller and lighter in weight than those used in the "Big Vein," the former having a capacity of 2 tons and weighing when empty 1780 pounds. The gauge of mine car tracks is 3 feet. The ventilation and drainage of both mines is natural. No mine pumps, fans, or mining machinery are used or needed. The tipple is of the usual pattern, dumping sidewise into the railroad cars.

THE MARYLAND COAL COMPANY.

The Maryland Coal Company's mines are Kingsland, Appleton, New Detmold, and Patton, all of which are drifts on the western rise of the "Big Vein" near Lonaconing.

Kingsland and Appleton mines.—On the northwestern edge of the town of Lonaconing and on the west side of Koontz Run, which empties into Georges Creek at that town, are the Kingsland and Appleton mines of the Maryland Coal Company. The coal mined is the breast coal of the "Big Vein," and the bottom benches also when the roof permits. One hundred and four men on the average were employed in these two mines in 1907 in hauling and handling the coal. The maximum daily output was 900 tons. The tipple on the west branch of the Georges Creek and Cumberland Railroad, close to the mouth of the Kingsland, serves for both the Kingsland and Appleton mines. A tram road (42-inch gauge) 2200 feet long connects the latter mine with the tipple. A long gravity plane inside of this mine lands the loaded mine cars in "trips" of 13 cars just outside of the Appleton mine, whence they are hauled by a locomotive weighing 10 tons to the tipple. A wire-rope of $1\frac{1}{8}$-inch diameter is used in operating the gravity plane in the Appleton mine. The rope passes five times around a set of wheels of 6 feet and 4 inches diameter at the top of the plane and 13 loaded mine cars going down the incline lift 13 empty cars to the top of the plane. In the Kingsland mine horses alone are used for haulage. In both the Appleton and

FIG. 10.—Sketch showing Track Arrangement at Appleton and Kingsland Mines, Maryland Coal Company.

Kingsland mines the coal is mined to the "rise," the drainage of both is natural, and no pumping machinery is required. A Guibal fan 16 feet in diameter produces exhaust ventilation for the Appleton mine and a fan of the same pattern 12 feet in diameter ventilates Kingsland, a 40-horse-power boiler supplying steam for the former and a 10-horse-power boiler the latter. The main tipple loads endwise into the railroad cars while an auxiliary tipple close to the main one supplies coal to the locomotives of the Georges Creek and Cumberland Railroad.

The Maryland Coal Company has opened up the "Tyson" seam over the mouth of the Kingsland mine from which the plane runs to the "Tyson" opening. The mine is provided with a Stine mine fan.

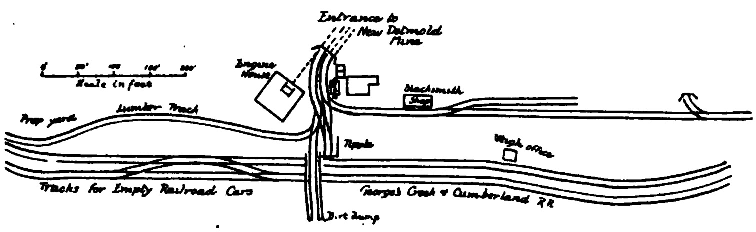

FIG. 11.—Sketch showing Track Arrangement, New Detmold Mine, Maryland Coal Company.

The *New Detmold and Patton mines* of the Maryland Coal Company are situated on the western side of the Georges Creek valley and of the coal basin, three-quarters of a mile southeast of Lonaconing. The tipple is at the end of the west branch of the Georges Creek and Cumberland Railroad and on the opposite side of the valley from the tipple of the Jackson mines of the American Coal Company. The coal from the Patton mine of the Maryland Coal Company is brought through the New Detmold mine to the New Detmold tipple. In 1907 52 employees were engaged in mining and shipping coal from these two mines and a number of horses were used in hauling the coal, in addition to a tail-rope haulage system. The maximum daily output of the two mines was 1000 tons of coal. The coal operated is the "Big Vein," which at this point of the Georges Creek valley lies high up on the hillside about the level of Georges Creek.

Only the breast coal is taken out of these mines and the props used are 8 feet long. The tail-rope system is operated by a 12 x 18-inch geared engine and 5-foot drum winding a ¾-inch wire-rope by which the mine cars are brought to and from the tipple in "trips" of 24 cars. The haulage engine is supplied with steam by an "Economic" boiler, both the engine and boiler being located in the engine-house close to the mouth of the mine and tipple. A Guibal fan having a diameter of 16 feet, driven by an "Economic" portable engine and situated about one-third of a mile northwest of the tipple and mouth of the New Detmold mine furnishes compressive ventilation to both the New Detmold and Patton mines. The coal is mined exclusively by pick and no mining machinery is used. No pumps are required to drain the mines as they are self-draining. The mine car tracks at all the mines of the Maryland Coal Company have a gauge of 42 inches and the mine cars weigh 1600 pounds when empty and have a capacity of 5000 pounds of coal. An ordinary back-balance tipple is used and an automatic pin-puller at the New Detmold mine. The tipple loads the coal sidewise into the railroad cars.

THE NEW CENTRAL COAL COMPANY.

The New Central Coal Company works the Koontz mine a mile northwest of Lonaconing and the "Big Vein" mine which is on the hill above and on the east side of the town of Lonaconing.

Koontz mine.—The Koontz mine, operated by the New Central Coal Company, is situated a mile northwest of Lonaconing and has its tipple on a siding or spur of the west branch of the Georges Creek and Cumberland Railroad. Both the coals of the Pittsburg or "Big Vein" and of the Upper Sewickley, or "Tyson," lying 110 feet above it, are mined by drift openings on the east side of Koontz Run, opposite and one-quarter of a mile above the Maryland Coal Company's Appleton mine. The coal from both beds is brought from the level of the mouth of the "Big Vein" to the tipple on the Georges Creek and Cumberland Railroad by a gravity plane 900 feet long. The main mine in the "Big Vein" is equipped with a tail-rope haulage system consisting of two return-tubular

boilers 60 inches in diameter and 16 feet long, of 75 horse-power each. A double engine 14 inches by 24 inches geared 3½ to 1 is used to operate three drums, two of which are 4 feet in diameter and one 5 feet in diameter, which wind a main haulage rope of ⅞-inch diameter and a tail-rope of ¾-inch diameter. The coal in the "Big Vein" averages 9½ feet thick and in the smaller vein above about 40 inches. The Koontz mine employed in 1907 on the average 106 men. The mines are ventilated by two fans of 20 and 10 feet diameters, having capacities respectively of 60,000 and 25,000 cubic feet of air pressure per minute.

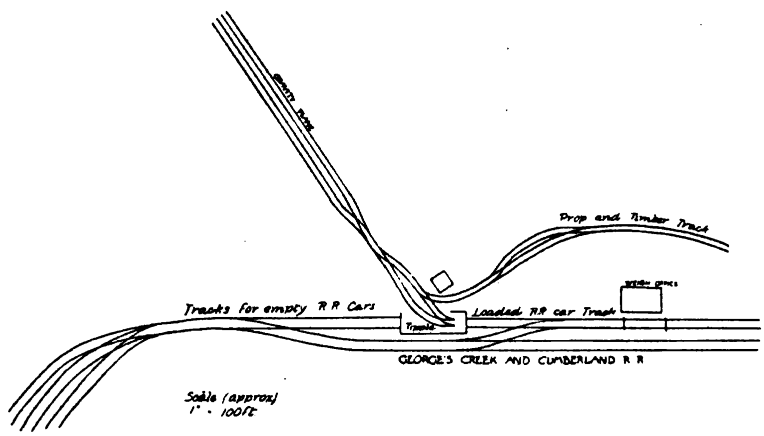

FIG. 12.—Sketch showing Tipple and Tracks, Koontz Mine, New Central Coal Company.

Compressive ventilation is used. The mines are partly self-draining and partly drained by the old workings of the Georges Creek Coal and Iron Company which lie between this mine and the center of the coal basin. No pumps are used and no mining machinery, the coal being cut entirely by pick-work. The usual system of room and pillar work used throughout the region is employed for taking out the coal. Two sizes of mine cars are used, one for each coal bed mined. The cars in use in the "Big Vein" or main mine have a capacity of two tons five hundred weight of coal and weigh when empty 1700 pounds. The gauge of track of both mines is 42 inches. The tipple is of frame and the coal is dumped endwise into the railroad cars. The tipple has a plain chute

furnished with an automatic and ingenious but rather complicated pin-puller. The "Big Vein" seam at this mine is something over 12 feet.

Enough rock above the coal is taken down in the headings in the small vein to allow headroom for men and mules to pass under. In working rooms only the coal is taken out and the small empty cars are pushed by the miners from the heading to the working faces and when loaded are run by gravity to the headings. A tail-rope haulage system operated by a stationary engine, located on the outside, brings the mine cars from the side headings in the interior of the mine to the head of the outside gravity plane near the level of the drift mouths of the "Big Vein" mine.

"Big Vein" mine.—The "Big Vein" mine was operated by the Coromandel Coal Company until July 1, 1907, when it was conveyed back to the New Central Coal Company, who formerly owned it. It is a drift mine in the outcrop of the "Big Vein" on the hill above and on the east side of the town of Lonaconing. The tipple on the east branch of the Georges Creek and Cumberland Railroad is close to the entrance to the mine. Twenty-five men on the average were employed in 1907. The ventilation and drainage are both natural and horse-power is used exclusively for haulage. The coal is mined by hand pick-work. The mine cars weigh 1760 pounds empty and hold two tons five hundred weight of coal. The gauge of tracks is 42 inches. The tipple is of frame, dumping sidewise into the railroad cars.

THE PIEDMONT AND GEORGES CREEK COAL COMPANY.

The Piedmont and Georges Creek Coal Company operates Washington mine No. 1 at the head of Washington Hollow between the Eckhart and Hoffman mines of the Consolidation Coal Company; Washington mine No. 2 one mile east of Frostburg; Washington mine No. 3 on the west side of Georges Creek about one-half mile south of Franklin Station; Washington mine No. 4 on the east side of Georges Creek directly opposite Washington mine No. 3; and Washington mine No. 5 opposite Franklin.

Washington mine No. 1.—The Washington mine No. 1 is located at the head of Washington Hollow between the Eckhart and Hoffman mines of the Consolidation Coal Co. It is about one mile east of the synclinal axis of the Georges Creek basin, and about one and one-half miles east of the town of Frostburg, Md.

The property, which covers about 200 acres, was secured by lease from the Consolidation Coal Company, and consists principally of old workings. The Washington mine, which was among the first operated in the Georges Creek field, was opened sometime in the forties, and was operated until 1852. It was then abandoned and lay dormant until 1900, when it was reopened, and over one-half million tons of coal which was supposed to have been lost has been regained.

The openings consist of three drifts made into the outcrop of the Georges Creek "Big Vein" or Pittsburg seam, and have an elevation of about 125 feet above the tracks of the Eckhart Branch of the Cumberland and Pennsylvania Railroad.

The mining is all pick-work, nor would the conditions of the pillars in the mines permit any other method. Sixty men were employed in 1907.

Timbering and advancing in these old workings is extremely expensive on account of the enormous amount of roof which has fallen, due to the long period during which the mines stood without timber. The advancing is also made difficult by the irregularities of the old workings, as in some places the coal was mined out clean, and the rock broke clear up to the surface, and in order to extend the road-ways around the sections that have been pillared, it is rather difficult and expensive, besides greatly affecting the grade and alignment of the road-ways, which are difficult to maintain, due to their proximity to the pillared territory.

The haulage is all done by horses, and it requires the best obtainable to stand the work, owing to the heavy grades (which average about 10%). The horses are worked tandem, and it requires two of them to pull one 2-ton car on this grade.

The cars are of a recent type, built of iron ribs. The wheels and axles both turn, making them very easy running. They hold from 2 to 2½

tons of coal when topped with lumps. The gauge of track is 3½ feet, and nothing but 16-pound steel T-rails are used in this mine.

The mine is ventilated with a 4-foot Robinson fan, which is directly connected to engine, the speed of which is about 350 revolutions per minute.

When the coal is delivered to the mouth of the mines, it is then collected in trips of six cars, and let down an incline plane a distance of 1600 feet. The plane is operated by machinery, consisting of two grooved wheels lying horizontal, and are so constructed as to permit an inch wire rope to pass around the front wheel three times, and the back wheel four times (this is to keep the rope from slipping). On the wheels is a brake attachment so connected to a lever that the operator has perfect control of the descending trip of coal cars at any point.

When the trip has landed at the foot of the plane, it is then passed over the mine scales, the weigh-man giving full credit to the miner for the contents of the car, whose check number appears on the car, after which the car is run on the tipple, and dumped into the railroad cars for shipment.

Washington mine No. 2 is located on the Eckhart Branch of the Cumberland and Pennsylvania Railroad near Eckhart and one mile east of Frostburg.

The territory embraces two tracts of 50 and 300 acres operated under a lease from Charles Leatham and the Consolidation Coal Company.

The first shipment of coal was made in October, 1902. The mine is a drift opening in the outcrop of the "Big Vein," penetrating the abandoned workings of the Ætna and Eckhart mines. Many obstacles were at first encountered in opening this mine, owing to accumulation of water and falls of roof, but after a means of draining had been found by removing falls, a much larger body of coal was found in the form of pillars than the first inspection of the accessible parts of the mine had led the company to expect. The coal is about 8 feet thick.

During the same year two drift openings were made on the same property in the outcrop of the Upper Sewickley (Tyson) coal. In 1905

a third opening was made about 400 feet south of the two former openings, which is now the main hauling way.

The coal runs from 3 feet 4 inches to 4 feet 6 inches in thickness. There are no slate partings or bone coal found in the seam in this territory, and in the 3500 feet of main entry which has been driven to a point near the eastern corporate limits of Frostburg no faults have been encountered.

The mine is opened on the double entry system, with 50-foot pillars between the entries and about 35-foot pillars between the rooms. The rooms are 18 to 20 feet wide.

The roof is blasted down in the entries to permit the use of 5-foot mules, and the shale blasted from the roof is stored on one side of the entry which is driven 16 to 18 feet wide.

The hard sandy shale which forms the cover over the coal makes an excellent roof, requiring very little timbering. No roof is taken down in the rooms.

The gauge of track is 42 inches—16-pound steel rails are used in the rooms and 35-pound rails on the main haul-ways.

Ventilation is maintained by an 8-foot direct-connected Robinson fan, driven at 150 revolutions per minute, working compressively, producing about 35,000 cubic feet of air per minute.

The mine cars are the iron-rib pattern, equipped with double brakes, having a capacity of about 1 ton of coal.

The tipple, which was built in 1906, is located about 1500 feet from, and 65 feet below, the mouth of the mine, making a grade on the tram-road leading to the tipple of about 4% in favor of the loads.

The dumping equipment consists of two automatic cross-over tipples, dumping into two railroad cars on separate tracks.

During 1906 an electric haulage plant was installed. The power-house is located near the tipple. The plant consists of one 150 H. P. tubular boiler with hot-water feed attachment, one 100 K. W. 250-volt belt-driven generator, simple engine, and three electric traction locomotives, one 10 tons and two 4 tons.

The overhead trolley system is used, and the small locomotives, besides

the usual trolley pole, are also equipped with an automatic reel attachment for carrying 300 to 500 feet of insulated cable conductor.

When it is desired to run on tracks where there is no trolley wire, the cable is connected to the trolley wire and the locomotive is propelled by current taken through the cable. The cable is automatically "paid out" as the locomotive runs away from the trolley wire, and automatically rewound in even layers with uniform tension when the locomotive returns. The small locomotives are used to gather the loaded cars from the rooms and entries to central points and placed on sidings where they are taken in trips of 25 to 50 cars by the large locomotive and hauled to the tipple.

The main haulage road is graded so that at no point does the grade exceed 2% against the loads. About 175 men were employed in 1907 and the daily capacity was about 850 tons. The mining is all pick-work.

Washington mine No. 3.—Washington mine No. 3 is located on the west side of Georges Creek about one-half mile south of Franklin Station, and directly opposite Washington mine No. 4.

The territory embraces about 500 acres, and was secured by a lease from Simon Roberts & Son, Silas Rees Coal Company, and others, together with 300 acres, which the company owns in fee.

There are two drift openings in the out-crop of the Lower Kittanning or "Six Foot" seam on the west side of the synclinal.

The entrance to the first opening is 104 feet from the tipple, the coal having an elevation of 50 feet above the railroad siding, which connects with the tracks of the Cumberland and Pennsylvania Railroad, the coal being conveyed from the tipple to the railroad cars through a 74-foot chute. During 1905 a second opening was made 500 feet north and 25 feet lower than the first opening, and connected by 350 feet of tram-road to a new tipple which is equipped with an automatic cross-over dump.

The new opening also furnishes a gravity drainage-way for the entire mine, having been started 8 feet below the lowest point in the coal basin in this territory and driven on an up grade of 2% for 400 feet through unconsolidated material to the outcrop of the coal.

The mines are opened on the double entry system, the entries being driven about 16 feet wide and 50-foot pillars between the parallel entries.

The rooms are made 16 to 18 feet wide and 35 to 40-foot pillars between them. On the south side of the mine the mining is pick-work exclusively, and the haulage is effected by mules.

On the north side of the mine one Sullivan continuous-cutter electric mining machine is used and the coal is gathered and hauled to the tipple by a 4-ton electric traction locomotive.

The coal is from 5 to 6 feet in thickness, covered by a hard sandy shale, which makes an excellent roof requiring but little timbering.

The cars used are of the iron-rib pattern equipped with double brakes, having a capacity of about 2 tons of coal.

The gauge of track in this mine, as in all other mines of this company is 42 inches. In the entries and rooms where the haulage is done by mules, 16-pound steel rails are used, and in the section of the mine where the haulage is done by the locomotives 35-pound rails are used. No wooden rails are used for track laying.

Ventilation is produced by a 12-foot direct-connected, steam-driven fan, working compressively at 120 revolutions per minute, producing about 20,000 cubic feet of air per minute. The maximum daily output of coal attained at this mine is about 900 tons. The average number of men employed in 1907 was 165.

During 1907 an electric power plant was added to the equipment of this mine. The plant consists of two horizontal 150 H. P. return-tubular boilers, with hot-water feed attachments, one 150 K. W. 250-volt belt-driven generator, and one 200 H. P. engine. The plant was completed in August and is centrally located with reference to mines Nos. 3, 4, and 5. The plant was installed with a view to furnishing power for the three mines but as yet only mines Nos. 3 and 5 are equipped for utilizing the power.

Washington mine No. 4, formerly the Hampshire Mine of the Piedmont-Cumberland Coal Company and acquired by the Piedmont and Georges Creek Coal Company in November, 1906, is located on the east side of Georges Creek and on the east side of the synclinal, directly opposite Washington mine No. 3.

The territory embraces about 420 acres, about 350 acres being covered

by a lease from the Morrison heirs, and the balance being owned in fee by the operating company.

The mine is a drift opening in the out-crop of the Lower Kittanning "Six Foot" coal, the elevation being a trifle higher than Washington mine No. 3.

The coal is mined by pick-work exclusively and the haulage effected by mules. The same system of mining is employed as at Washington mine No. 3.

Ventilation is produced by a 12-foot direct-connected fan working compressively at 100 revolutions per minute, producing about 20,000 cubic feet of air per minute.

The cars are the iron-rib pattern equipped with double brakes, and hold from 1 to 1½ tons of coal when topped with lumps. Sixteen-pound steel rails are used throughout the mine.

The number of men employed at this mine in 1907 was about 70, and its daily capacity was about 275 tons. Drainage is principally natural, assisted by a 2-inch siphon.

The coal is let down a short gravity plane from a point near the mouth of the mine to the tipple, and then dumped into the railroad cars, which are placed on a siding east of, and connecting with, the tracks of the Cumberland and Pennsylvania Railroad.

Washington mine No. 5 is located west of the synclinal axis of the coal basin, and opposite Franklin Station on the Cumberland and Pennsylvania Railroad. The property contains about 230 acres, is known as the Michael's farm, and has been purchased by this company.

There are three drift openings in the outcrop of the Barton or Bakerstown seam about 450 feet above Georges Creek. The mines were opened in the fall of 1906, and the first shipment of coal was made in August, 1907.

The mines are opened on the double-entry system, with 50-foot pillars between the parallel entries, and 40-foot pillars between the rooms. In addition to pick-mining, one Sullivan continuous-cutter electric mining machine is used. The coal seam is about 4 feet in thickness. About 47 men were employed in 1907.

The haulage is exclusively electrical. The trolley traction system is used. The locomotives are of the same type and size as those used in Washington mine No. 2.

The cars are of a recent type, having iron ribs, to which the side and bottom board are bolted. The axles are round, and so constructed as to permit them to turn with the wheel. The cars will hold about 1 to 1½ tons of coal when topped with lumps.

The gauge of track is 42 inches. On the entries 30-pound T-rails are used, and in rooms 16-pound T-rails. The entry rails are permanently bonded with copper wire, and the room rails are bonded with adjustable iron bonds.

Ventilation is produced by a 16-foot direct-connected steam-driven fan, working compressively, but built to work exhaustively, as well as compressively.

The mines are connected by tram-road with a tipple located about 200 feet from the top of the plane, where the coal is weighed in the mine cars, and then dumped on an automatic cross-over tipple into cars having a capacity of about 5 tons. The large cars are let down a gravity plane 2200 feet in length to a tipple on the railroad siding, where the cars are dumped on an automatic cross-over tipple into a steel chute 20 feet in length, which conveys the coal into the railroad car.

The chute is provided with adjustable screen bars for separating the lump from the fine coal. For loading run-of-mine coal, steel sheets which are hinged to the sides of the chute are let down on the screen bars, covering the entire screening surface.

THE PIEDMONT MINING COMPANY.

The Piedmont Mining Company is operating at the present time only the Pekin mine, the Moscow mine having been worked out during the past year. The Pekin mine is situated on the hill west of the town of the same name.

Pekin mine.—The Pekin mine which adjoins the New Detmold of the Maryland Coal Company is operated by the Piedmont Mining Company; this company owning in fee the old property, which formerly belonged

to the Atlantic and Georges Creek Consolidated Coal Company. They are working some coal which underlies the old Atlantic property, but the major part of the coal is leased from the Maryland Coal Company. A tipple is located at the upper end of the town of Pekin and is equipped to load run-of-mine, lump, or screened coal. The coal is hauled about four miles by tram-road by means of a steam locomotive and is run down a gravity plane about 900 feet long to the dump, which is located on the Cumberland and Pennsylvania Railroad. The company at the present time has seven openings, located above Laurel Run along the crop of the "Big Vein" coal and expects to extend the tram-road about a mile beyond No. 7 opening and make two more openings in order to get to the end of the "Big Vein" territory. The coal mined is strictly "Big Vein." The mines are ventilated by natural means and horses are used to haul the coal to the mouth of the mine.

Some prospecting has been done for the "Tyson" seam, but up to this date it has not been developed sufficiently to warrant shipping any for the market. There is quite a large area of this coal underlying the property in addition to all of the other seams, which are below the "Big Vein." The Barton "four foot" or Bakerstown seam underlies the entire property, and at the tipple is about fifteen feet under water level. The company employs at present about 50 men in mining the "Big Vein" coal.

THE MIDLAND MINING COMPANY.

The Midland Mining Company operates the New Enterprise mine, near Midland, and the Trimble mine on Federal Hill, to the south of Mount Savage.

New Enterprise mine.—This mine is on a spur of the Cumberland and Pennsylvania Railroad, a half-mile northeast of Midland, and is operated by the Midland Mining Company under a lease from the Consolidation Coal Company. The seam mined is the "Big Vein," which has about the same thickness as in the mines of Ocean No. 1. The coal is mined by two drift openings driven into the out-crop on the west side of Neff's Run. Thirty-three men were employed in the mine in 1907. The

loaded mine cars are hauled by horses from the mines to the tipple over a tram-way 4000 feet long. The company is now installing a wire-rope haulage plant consisting of a single-drum 85-horse-power hoisting engine by which the loaded cars will be lifted to the surface up an incline 1200 feet long. The coal is mined by hand pick-work. The mines are self-draining and no artificial appliances are used for ventilation. The gauge of mine tracks is 3 feet. The mine cars weigh when empty 1780 pounds and have a capacity of 2½ tons loaded. A plain tipple, having an iron T-rail back-balance, loads the coal sidewise into the railroad cars.

Trimble mine.—In 1903 the Midland Mining Company also opened a coal bed on Federal Hill about 1½ miles south of Mt. Savage on the Winfield Trimble tract. The coal in the lower opening is the Lonaconing seam and has a thickness of about 4 feet. Higher up the Franklin seam has also been opened but this coal contains considerable bone and slate. It has been claimed that the coal mined belongs to the lower bench of the Pittsburg bed but it is probably a lower seam. Mules haul the coal over a tram-way from the main opening to the head of a gravity plane, 1300 feet long, which delivers it to the tipple. The latter is on a siding of the Cumberland and Pennsylania Railroad between Morantown and Mt. Savage. Sixteen men were employed during 1907.

THE BOWERY COAL COMPANY.

The Bowery Coal Company is operating the Bowery mine of the Borden Mining Company and a part of the old Johnson mine of the New Central Coal Company, which are situated at Midlothian on the south side of the valley of Winebrenner Run.

Bowery mine.—This mine which was abandoned with the idea that no more coal could be secured is located in the "Big Vein" and by the method of mining introduced is producing considerable coal from previously worked-over areas. The coal is shipped over the Midlothian branch of the Cumberland and Pennsylvania Railroad. The ventilation is by natural means. The company is contemplating the development of the Tyson seam in the vicinity of the Bowery mine.

THE H. AND W. A. HITCHINS COAL COMPANY.

The H. and W. A. Hitchins Coal Company operates the Borden mine about one mile north of Frostburg on a lease from the Borden Mining Company.

Borden mine.—This mine is a drift in the outcrop of the "Big Vein" at the north end and on the western edge of the Georges Creek coal basin. An inside haulage road has been extended through the property which has advantageously opened up the coal that was thought to have been worked out. This road also serves for drainage purposes. The ventilation is by natural means. The coal is brought from the mine to the top of a long tram-road and gravity plane. The tipple is located on the Cumberland and Pennsylvania Railroad close to the tipple of the old Frost mine and across the valley of Jennings Run from the tipple of Union mine No. 1. Sixty-eight men on the average were employed by the company during 1907.

THE PHŒNIX AND GEORGES CREEK MINING COMPANY.

The Phœnix and Georges Creek Mining Company operates the Phœnix and Elkhart mines, which are situated on the west side of the Georges Creek valley, not far to the northwest of Phœnix.

Phœnix and Elkhart mines.—About a mile above Franklin Station on the Cumberland and Pennsylvania Railroad on the west side of the railroad and of Georges Creek is the tipple of the Phœnix and Georges Creek Mining Company. This tipple is on a siding of the Cumberland and Pennsylvania Railroad. The siding branches from the main track and crosses Georges Creek one-quarter of a mile below the tipple. Both the "Big Vein" (Phœnix mine) and the "Four-foot" or Bakerstown coal beds (Elkhart mine, a new mine opened in 1904) are operated by this company with drift openings and the coal from both is brought to the one tipple. A 3-rail gravity plane 800 feet long connects the opening in the Bakerstown coal bed with the tipple, and another 3-rail gravity plane 1575 feet long brings the coal in "trips" of two cars from the "Big Vein" mine to the top of the lower plane, to which it is transferred one car at a time and lowered to the tipple. The improvements for this

operation were put in in 1902. The coal is mined by the room and pillar system, the rooms being 12 feet wide with 50 feet between points or centers. Props 11 feet long are used in the upper mine in the "Big Vein." No mining machinery is used. The coal beds operated by this company lie on the western pitch of the basin and the mines are naturally drained and ventilated. The cars used are of more modern construction and different from those common to the region. The sides are held together by strap-iron "binders" passing around the outside of the body of the car. The cars used in the "Big Vein" mine have a capacity of 2¼ tons of coal and when empty weigh 1300 pounds. The gauge of tracks is 42 inches. The cars used in the Bakerstown seam are of similar construction to those used in the "Big Vein" mine. The tipple is the ordinary back-balance with frame trestle supports, and dumps the coal sidewise into the railroad cars. About 75 men were employed in 1907.

THE BRAILER MINING COMPANY.

The Brailer Mining Company, formerly the Georges Creek and Bald Knob Coal Company, owns the Brailer mine situated about one mile and a half north of Mount Savage.

Brailer mine.—This mine consists of three drift openings in a detached area at the extreme northern end of the Georges Creek coal basin. Two of these openings are in "Big Vein" coal and the third in the Redstone seam, 17 feet above, but the property has not been in operation for the past three years. A tram-road 1½ miles in length leads from the mine to an inclined plane 1800 feet long at the base of which is a substantial tipple on a spur of the Cumberland Basin Coal Company's railroad. The tipple is provided with a screen for the separation of the coal for smithing purposes. The company owns an 18-ton locomotive and 48 mining cars of two-ton capacity. The mine is naturally drained and ventilated.

THE MOSCOW-GEORGES CREEK COAL MINING COMPANY.

The Moscow-Georges Creek Coal Mining Company operates two mines, Moscow No. 2 and No. 3, situated between Moscow and Barton, from which they ship over the Cumberland and Pennsylvania Railroad.

Moscow No. 2 mine. Moscow No. 2, formerly the old Pickell mine, is in the "Big Vein" on the west side of the Georges Creek Valley, the coal being reached by a series of openings at a point where they are able to penetrate the hill and reach some of the old pillars that indifferent mining left there. The coal is reached by two long inclines, a tram-road running right and left from the head of the upper plane. Ventilation is natural. Sixteen men on the average were employed in Moscow No. 2 during 1907.

Moscow No. 3 mine.—This mine is in the Bakerstown or "Four-foot" seam and is also on the west side of Georges Creek, below Moscow No. 2. The mine is near the center of the syncline not far above water-level, although the coal is shipped over the same tipple as Moscow No. 2. The ventilation is for the most part natural although a small furnace is located at one of the openings. Twelve men on the average were employed in this mine during 1907.

THE BARTON MINING COMPANY.

The Barton Mining Company operates the mine called Moscow No. 1, which it leases from the Moscow-Georges Creek Coal Mining Company. This mine is situated on the east side of the Georges Creek Valley one-half mile above Barton.

Moscow No. 1 mine.—This mine is in the Bakerstown or "Four-foot" coal bed and was opened by the Moscow-Georges Creek Coal Mining Company in 1902. A short tram-way connects the mine with the tipple from which coal is shipped over the Cumberland and Pennsylvania Railroad. The company reports an average of seven men employed during 1907.

THE FROSTBURG FUEL COMPANY.

The Frostburg Fuel Company operates Tyson mine No. 2 near Frostburg.

Tyson mine No. 2.—This mine has been leased from the Consolidation Coal Company and the present operators, the Frostburg Fuel Company, are supplying coal for local uses in Frostburg only. The mine is a small

drift mine with natural ventilation. Six men were employed on the average during 1907.

THE CHAPMAN COAL MINING COMPANY.

The Chapman Coal Mining Company operates the Swanton mines at Barton, the coal being shipped over the Cumberland and Pennsylvania Railroad and thence via the Baltimore and Ohio and Pennsylvania Railroads.

Swanton mines.—The Swanton mines consist of operations in both the Tyson and Bakerstown seams. The Tyson is the more important operation, the coal being about 6 feet thick and of good quality. The ventilation is natural, the workings being near the surface, several openings occurring at different points around the hill. The mine in the Bakerstown seam is located nearly at the foot of the hill and is also a drift mine. Shipment from both mines is made over the same dump. The tipple is on a siding of the Cumberland and Pennsylvania Railroad close to Barton Station and about 600 feet north of the tipple of the American Coal Company's Caledonia mine. A short 3-rail gravity plane connects the mine with the tipple. The coal worked in this mine is known locally as the "four-foot" seam and is a fine steaming fuel, but is somewhat high in sulphur. The mine is naturally drained and ventilated. The company some years ago relaid the track of the old Swanton plane and reopened the "Big Vein," taking the coal near the out-crop which was not mined out by the Swanton Company. About 75 men were employed on the average in the Swanton mines during 1907.

CUMBERLAND-GEORGES CREEK COAL COMPANY.

The Cumberland-Georges Creek Coal Company operates the Penn mine in the Bakerstown seam on the west side of Georges Creek about one-half mile north of Franklin Station. The Franklin mine in the Lower Kittanning, the Mooredale mine in the Upper Freeport, and the Ferndale mine in the Franklin seam are to be opened up by the company. Development work has been carried on but the operations are not sufficiently far advanced to furnish shipping coal.

Penn mine.—The Penn mine is a drift in the Bakerstown coal bed, the coal varying from 2½ to 3½ feet in thickness. The coal is mined by pick-work. The mine has a natural drainage and in December, 1907, an improved fan was installed to take the place of the former wooden air-stack. The ventilation is by natural methods. A 3-rail gravity plane 1300 feet long and a tram-road from the top of the drift connects the mine with the tipple, which is situated on a siding of the Cumberland and Pennsylvania Railroad. The tipple is a frame work covered with corrugated galvanized iron and with two chutes, loading the coal endwise. The sidings are long enough to contain 30 empty and 30 loaded cars. The gauge of the mine-car track is 42 inches. The mine cars weigh when empty about 1200 pounds and hold one ton twelve hundred weight of coal. The company employed on the average 25 men during 1907.

THE FROSTBURG COAL MINING COMPANY.

The Frostburg Coal Mining Company operates the Morrison mine at Morrison Station.

Morrison mine.—The Morrison mine, now operated by the Frostburg Coal Mining Company, is situated at Morrison Station of the Cumberland and Pennsylvania Railroad on the east side of the railroad and east of the axis of the coal basin. Two coal beds, the Upper Freeport and Bakerstown, are worked by drifts and the coal brought to one tipple. The opening in the lower or Upper Freeport seam is 140 feet from the tipple and just high enough above it to afford an easy grade in favor of the loads from the mine to the tipple. In 1907 the maximum capacity of this mine was 100 tons of coal per day and 27 men were employed in it. In 1902 the upper coal bed was opened, and in 1903 the output was from both seams. A 3-rail gravity plane connects the upper coal bed with the tipple. This upper coal bed is the one worked by the Union Mining Company at their Potomac mine and in the mines of the Moscow-Georges Creek Coal Company at Barton, the lower coal bed passing under the level of Georges Creek between Barton and Morrison. The thickness of the upper coal bed varies in this mine from 2½ to 4 feet.

In these mines five Ingersoll-Sergeant coal-mining machines are used

at times but usually only three of them are in operation at once. The coal-mining machines are operated by compressed air, which is supplied to them at a pressure of about 85 pounds to the square inch by an

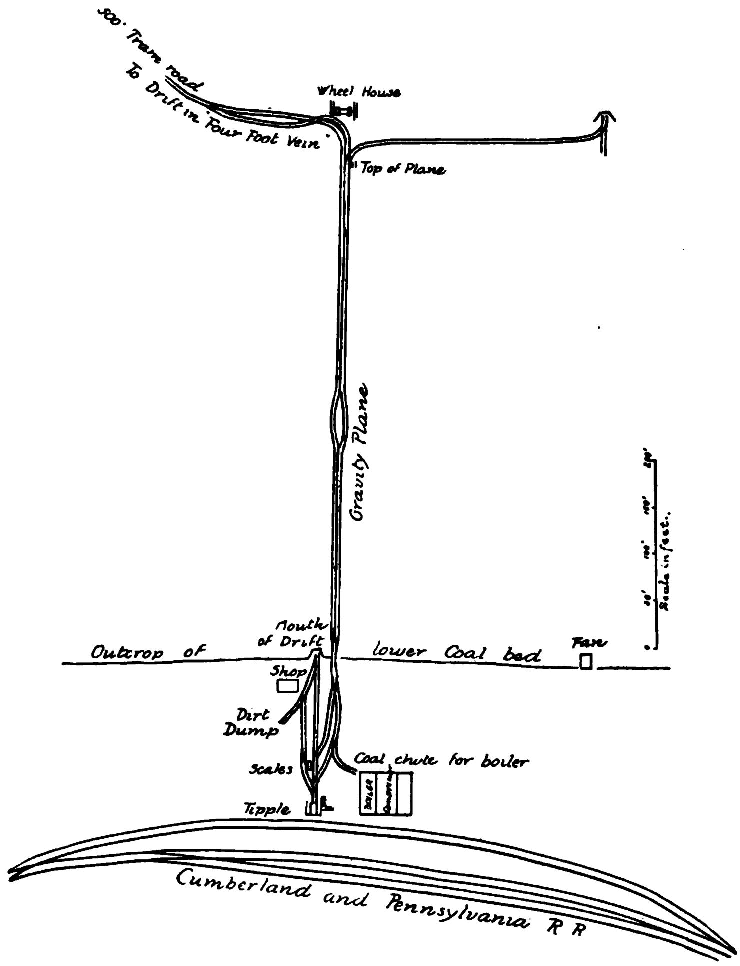

FIG. 13.—Sketch showing Tipple and Plane, Morrison Mine, Frostburg Coal Mining Company.

Ingersoll-Sergeant straight-line compressor with steam cylinder 22 x 24 inches and 22¼ x 24¼ air cylinder. The compressor is intended to run ten mining machines. The lower mine is ventilated by a fan 10 feet in

diameter which forces the air into the mine. A 100-horse-power return-tubular boiler 16 feet long and 6 feet in diameter supplies steam to the air compressor and fan. The upper mine is naturally ventilated, assisted by a wooden stack at the opening on the north side of the wheel-house at the head of the plane. Both mines are naturally drained. The Deepwell pump (6 x 12 inches, capacity 500 gallons per hour) is used for cooling the compressor. The tipple is built of wood 20 feet high, of the pattern common to the region, with an additional chute beneath the main chute for loading box cars. When the lower chute is used the bottom of the upper or main chute is lifted out. The mine cars weigh 1000 pounds and have a capacity of 1900 pounds of coal. The gauge of mine-car tracks is 42 inches.

THE GEORGES CREEK BASIN COAL COMPANY.

The Georges Creek Basin Coal Company, which was known prior to June, 1907, as the Braddock Coal Company, operates the Short Gap mine near Eckhart.

Short Gap mine.—This mine is a double drift opening in the Upper Freeport seam on the north side of Braddock Run, the tipple being located across the valley on the Eckhart Branch of the Cumberland and Pennsylvania Railroad to which the coal is taken in buckets by means of an aerial tramway rope-haulage system, which is worked by an engine and boilers located near the mine. The loaded mine cars are first emptied in a storage bin near the mouth of the mine from which the coal is loaded into buckets and transferred across the valley to the tipple as needed for shipment. A switch will be installed shortly which will permit of the shipment of 600 tons per day. The mine was first opened in 1903 and 10 men were employed on the average during 1907, since which time there has been an increase, until 30 are now employed. A 14-foot Crawford and McCrimmon fan has been recently installed. The company will shortly open the Lower Kittanning and Parker seams.

THE DAVIS COAL AND COKE COMPANY.

The Davis Coal and Coke Company operates the Buxton mine near the mouth of the Savage River two miles above Westernport and the

Henry mine just across the Maryland line at Henry, West Virginia. It is the plan of the company to reach the coal on the Maryland side of the line from the present shaft. A description of the latter mine is therefore included.

Buxton mine.—The Davis Coal and Coke Company operates a drift opening in the Lower Kittanning or "Six-foot" coal bed, on the east side of the North Branch of the Potomac River at the mouth of the Savage River, two miles above Westernport. The mine was opened in 1895. The coal is brought across the river on a steel bridge to the tipple on the West Virginia Central Railroad.

The mouth of the drift is 75 feet above the level of the bridge and the coal is lowered to the tipple by a rope haulage. The mine was opened into a large territory but all the north entries with the exception of the first and second right, have been driven into sandrock and all but one pair of tunnels have been abandoned. The main tunnels have been driven 1700 feet in this sandrock, but the present indications are that they are again entering a normal section of Kittanning coal.

The mine is now producing 700 tons per day and employed on an average 150 men during 1907. The coal is mined exclusively by pick-work. On acount of the heavy grade against the loaded cars the gathering is largely done by mule teams, there being 10 of these teams in service at the present time. From other parts of the mine where the grades are more favorable, gathering is done by eight single mules.

The coal is brought to the drift mouth by an endless rope-haulage system and the grades in the mine vary from 0 to 5%. Coal is worked on the room and pillar system with rooms and entries 18 feet wide, pillars 25 feet wide. Pillars are drawn as soon as the rooms are completed. The roof at this mine is excellent and requires little timbering.

A cross-section of the coal is as follows:

Draw slate		3″	
Bone coal		2″	5′-1⅛″
Coal		5″	
Bone coal		5″	
Coal	1′	8″	
Slate		1″	
Coal	2′	4″	

Four feet 6 inches of this coal is marketable, 95% of which is regained after drawing the room and entry pillars. The present working places are located about one mile from the mouth of the drift.

Mine cars weigh 1600 pounds when empty and have a capacity of 1 to 1¾ tons of coal. The gauge of track in this drift is 42 inches. The mine is free from gases and is ventilated by a 10 and 12-foot fan. The steam plant consist of five boilers generating 400 horse-power and is used to furnish steam to drive the endless rope-haulage engine, the plane engine, and a small compressor which provides power for the rock drills and the five pumps in use.

The coal from this mine is loaded and shipped as mine-run coal.

Henry mine.—At Henry, West Virginia, just across the Maryland line near the southern corner of Garrett County, the Davis Coal and Coke Company in 1901 and 1902 sank two shafts to the Thomas and Davis coal beds, as the Upper Freeport or "Three-foot" and the Lower Kittanning or "Six-foot" seams are respectively called by that corporation. An area of coal lying beneath the Maryland side of the Potomac River will eventually be worked from this plant but as yet the workings of this mine are confined to the coal which lies beneath the surface of the State of West Virginia. At this plant each of the above-named coal beds is opened to produce 1000 tons of coal per day. At present only the upper or "Thomas" (Upper Freeport) coal bed is worked. The Upper Freeport coal bed at this mine has an average 3 feet 3 inches of coal, above which is a succession of thin strata of bone coal and soft coal to a total height of 5 feet from the bottom of the coal bed. Above this is a tough sandrock which makes an excellent roof. The Upper Freeport or "Thomas" coal lies 197 feet beneath the surface at the Twin Shaft (No. 2). It is reached and operated through two of the hoisting compartments of the Twin Shaft. The other two of the hoisting compartments of this shaft extend from the surface downward 419 feet to the Lower Kittanning or "Davis" coal bed. This coal bed has an average of 43 inches of coal in the lower bench and 30 inches in its upper bench. The two benches are separated by a binder of variable thickness.

No. 1 shaft has three compartments 7 x 12 feet, two hoist-ways, and

one airway. The hoist-ways are used to raise and lower men, and supplies to both seams. The shaft is 432 feet deep and is sunk 7 feet below the bottom of the Davis coal bed. Run-of-mine coal can be loaded on two railroad tracks from the tipple of shaft No. 1. The latter is 100 feet from the shaft and is connected with the main boiler plant by a steel trestle. A larrie, operated by a trolley, delivers coal over the trestle to the boilers. The boiler plant consists of six 150-horse-power steam tubular boilers and one Stilwell-Bierce and Smith-Vaile heater No. 5.

The power-house equipment is one Ingersoll-Sergeant straight-line compressor, 24 x 30 inches, which supplies air through a 6-inch pipe-line to 20 Ingersoll-Sergeant coal-cutting machines. One Westinghouse generator, 75-horse-power, is used for operating the conveying machinery of the tipple and for lighting the town. One Ball-Wood engine and a Bullock generator of 200 kilowatts are used for running four electric motors in the mine. The hoisting engines of both shafts are run by steam, supplied from the boiler plant through 7-inch pipes which branch from the main 10-inch line. The hoisting engines of No. 1 shaft are geared and its winding drums are 7 feet in diameter and 3 feet wide. A geared clutch on one of these drums controls the length of rope and allows the engineer to lift at will from either seam with either cage. For shaft No. 2 of the main hoisting shaft, there are two sets of 24 x 36-inch direct-acting hoisting engines equipped with steam emergency brakes, safety hand brakes, and a steam reversing brake. The winding drums of shaft No. 2 are 7 feet in diameter and 8 feet long. At both shafts 1¼-inch steel ropes are used for hoisting cages. Both mines are ventilated by a fan 13 feet 2 inches by 7 feet of Capell pattern. The fan is located at shaft No. 1, is driven by a 16 x 19-inch direct-connecting engine, and is constructed to either force or exhaust the air. The fan structure is of brick with a sheet-iron cover.

The two 16 x 19 x 18-inch Smith-Vaile pumps, operated by steam, lift the water from the "sump" of the lower coal bed to the "sump" of the upper seam. One of these pumps is usually sufficient to keep the mine in the lower seam free from water. The second pump is only used in cases of emergency. At the "sump" of the upper seam, which is

located close to shaft No. 1, two 24 x 12 x 30-inch Young pumps with 12-inch suction and 10-inch discharge are installed and lift the water of both mines to the surface.

The capacities of each of the last two named pumps is 600 gallons per minute, but only one of them is now needed to keep the mine free from water.

The underground workings in both the Upper Freeport or "Thomas" and the Lower Kittanning or "Davis" coal beds are developed upon the same plane. Near the shafts two sectional headings diverge 120 degrees from each other. From the sectional headings butt entries are driven with point lines 60 feet apart. Rooms are made 20 feet wide or the width of five cutting machine boards. Two 13-ton electric motors and two gathering motors are used for haulage in the mine in the Upper Freeport seam. The main underground motor tracks of this mine are laid with 56-pound T-iron and the mine cars are built to contain 1.7 tons of coal. The coal from the main hoisting shaft No. 2 first passes over a screen and is delivered into the picking tables where the slate is taken out by hand. The cleaned coal is loaded into the railroad cars. The picking tables are run by electric motors at a slow speed. The slate taken from the coal on the picking tables is conveyed by belts to bins from which it is loaded into cars and taken to the slate dump. The mine employs 300 men at the present time.

THE WACHOVIA COAL COMPANY.

The Wachovia Coal Company operates the Waco mine near Clarysville.

Waco mine.—This mine, commonly known as the Montell Tunnel, was driven into the side of Dans Mountain cutting the Lower Kittanning seam near the present face of the tunnel and is the only point in this portion of the mountain where this seam is being worked. The coal stands at a high dip as it is near the outer edge of the synclinal basin. The tunnel is at the present time being driven through the mountain. Compressed-air mining machines of the puncher type are employed in mining the coal, which is shipped over the Georges Creek and Cumberland Railroad. Fifty-two men were employed on the average during 1907.

THE CUMBERLAND BASIN COAL COMPANY.

The Cumberland Basin Coal Company operates two mines in the Lower Coal Measures at Pamosa known as the Bond and Parker mines.

Bond and Parker mines, formerly known as the McGlone and Stafford mines, are openings in the Bluebaugh and Parker seams respectively. They are situated on the southeast side of the valley of the North Branch of Jennings Run, one-half mile northeast of Barrelville. The mines are on the east rise of the Georges Creek coal basin syncline and close to the point where the syncline passes out of Maryland into Pennsylvania. The Parker mine is a drift opening while the entrance to the Bond mine is a short slope from the level of the Parker seam to the Bluebaugh, which is about 30 feet deeper. At this locality the slope strikes the Bluebaugh coal bed just above the water-level line of the North Branch of Jennings Run. The entrances to both mines pass through the workings of old mines, which were operated many years ago before even the "Big Vein" was commercially worked. After passing through the old workings the development of the mine is by a series of double headings driven slightly to the rise in the line of strike of the coal beds. The coal from both mines is hauled by mules to a tipple which serves for the shipment of the output of both. The tipple is located across the North Branch of Jennings Run from the mines, on a siding of the Cumberland Basin Coal Company's railroad a half-mile from the junction of the latter with the Cumberland and Pennsylvania Railroad. The mines are naturally drained into the North Branch of Jennings Run and their ventilation is assisted by wooden stacks. The property has been acquired by new interests, which have added largely to its equipment, putting up new buildings as well as constructing a new air-shaft and furnace. Haulage roads have been made higher with more room on the sides, and roads and drainage have been greatly improved. The company employed about 35 men on the average during 1907.

MC MULLEN BROTHERS.

McMullen Brothers own the Partridge Run mine at Barrelville on the main line of the Cumberland and Pennsylvania Railroad.

Partridge Run mine.—This mine is in the Bluebaugh seam, which is faulty at this point so that operations have been suspended. The mine is a drift, with a long tram-road and gravity plane to reach the tipple. It was operated with considerable success and has penetrated the mountain about 600 feet from the opening. The fault encountered consists of a mixture of soft earth with the coal and renders it useless. It is the intention of the owners, as soon as conditions warrant, to drive a heading across the fault until they again reach coal of the quality they mined before coming in contact with the fault. There is every reason to believe that they will find a body of coal sufficient in quantity and quality tc invite profitable development. The company reports no output in 1907 They contemplate opening the Parker and Lower Kittanning seams which are found on the same property.

GARRETT COUNTY.

GEORGE C. PATTISON.

George C. Pattison operates the Pattison mines one-quarter of a mile west of Bloomington, the tipple being situated on a siding on the main line of the Baltimore and Ohio Railroad.

Pattison mines.—These mines are operated under a lease from the Empire Coal Company and the Jones and Owens estates, and the coal from both is shipped over one tipple, which has a separate chute for each mine. The opening in the Lower Kittanning or "Six-foot" bed is a drift 35 feet above the level of the Baltimore and Ohio Railroad and is connected with the tipple by a short tram-road. The drainage is natural and the coal is mined exclusively by hand. The mine is ventilated by a small fan. Where the coal bed has its best development in this mine it shows a little over 4 feet. The roof is a fire-clay shale, varying in thickness from nothing to 18 inches, above this fire-clay is a strong sandstone. The bed is subject to squeezes in which the thickness of the coal is considerably reduced and a number of thin clay bands have been encountered in the workings of the mine.

The upper mine in the Bakerstown or "Four-foot" coal bed lies 410 feet immediately above the opening in the "Six-foot" bed, and is con-

nected with the tipple by a gravity plane 1010 feet long. The thickness of the coal bed averages 28 inches with 15 inches of bone coal above it and about 5 inches of bone and shale below. The ventilation and drainage are natural and the coal is mined by pick-work. The mine-car track gauge of both mines is 3½ feet. The mine cars weigh 1000 pounds when empty and contain 1½ tons of coal. Forty-nine men were employed in both mines on the average in 1907.

THE BLOOMINGTON COAL COMPANY.

The Bloomington Coal Company operates the Bloomington mine near Bloomington.

Bloomington mine.—The Bloomington mine is an old mine that was reopened by the Bloomington Coal Company September 1, 1907. It is a drift opening in the Lower Kittanning seam. The pillar and room system of mining is followed and all the coal is mined by pick-work. A small fan is used for ventilating the mine. The capacity is 300 tons daily. The coal is loaded directly in the cars at a siding on the main line of the Baltimore and Ohio Railroad. The average number of men employed was 31.

THE MONROE COAL MINING COMPANY.

The Monroe Coal Mining Company operates two mines known as Elk Run No. 1 and Elk Run No. 3 on the Maryland side of the Potomac River opposite Barnum Station on the Western Maryland Railroad, from which point shipment is made.

Elk Run mines Nos. 1 and 3.—Elk Run No. 1 is in the Lower Kittanning or "Six-foot" seam and was formerly known as the Barnum mine of the Watson-Loy Coal Company. Elk Run mine No. 3 is in the Bakerstown or "Four-foot" seam and was known until 1902 as the Loy mine of the same company. The river has been bridged and the coal from both mines is brought across to the tipple on the Western Maryland Railroad on the West Virginia side. The level of the opening in the "Six-foot" seam is just high enough to give a descending grade suitable for mule haulage from the mine to the tipple. The "Four-foot" seam

is high up on the hill above the river and required a gravity plane 1350 feet long and a tram-road at the top of the plane to connect the mine with the tipple. Thirty-two men were employed in the Elk Run No. 3 with four mules for haulage, and 87 men employed in the Elk Run mine No. 1 and eight mules for haulage during 1907. The output of the former is 100 tons, of the latter 250 tons daily. The railroad siding has room for 40 empty cars and was extended in 1903 to connect with the Western Maryland Railroad above, as well as below, the tipple.

The equipment of the Barnum mine consists of two horizontal boilers of 125-horse-power each. These supply an Ingersoll-Sergeant straight-line air compressor, which in turn operates rock drills in No. 1 mine and a Stine fan in No. 3 mine. Punching machines were discontinued in 1905. The air compressor has a 24 x 36-inch steam cylinder and a capacity of 1400 cubic feet of air per minute. The boilers, compressor, and its receiver, the latter being 30 inches in diameter and 22 feet long, are located on the West Virginia shore near the tipple, and the compressed air is conveyed across the Potomac River through a 6-inch pipe supported by a wire suspension bridge. The 6-inch pipe-line extends 500 feet into the mine in the lower "Six-foot" seam, where it is reduced to 4 inches diameter. Pipes 1½ inches in diameter lead into the rooms and supply air to work the coal-cutting machines. The coal in the upper or "Four-foot" seam is mined by pick-work. The coal for the boilers is run down a short incline from the tipple to the boiler-house and the empty cars are hoisted up this incline and returned to the tipple by a small hoisting engine stationed in the boiler-house. The engine winds a wire-rope which passes around a bull-wheel at the top of the incline.

Besides the main chute the tipple has an additional chute for loading wagons for local use. The main chute is constructed with a folding bottom which can be lifted or folded and the coal loaded into box cars on the second track of the railroad siding which passes under the tipple. In addition to the steps for the use of the men with which tipple structures are usually provided, the tipple of this company has an incline which is intended as a travelling way for mules to and from the mines.

The room and pillar system of mining is used in both of the mines

of the Monroe Coal Mining Company. The main entries are 9 feet wide with pillars of coal 75 feet between the entry and the air courses. Branch entries are 15 feet wide with pillars of coal 30 feet wide between the parallel entries. Rooms are driven 20 feet wide. The pillars between rooms are 25 feet wide.

The rooms are usually 300 feet long. Three hundred and forty feet are left between each pair of branch entries and a pillar of 40 feet is allowed to remain between the end of the rooms and the air courses to protect the latter until the pillars are drawn. In the "Six-foot" seam the height of the coal is sufficient to afford head room for men and mules without taking down the roof, while in the upper or "Four-foot" seam 2 feet of the roof is taken down in headings. The coal seam in the Barnum mine is over 5 feet, with slaty partings and some bony coal, while scarcely 3 feet of workable coal is found in the Bakerstown seam.

The workings of the "Six-foot" seam are ventilated by a fan 10 feet in diameter having a capacity of 40,000 cubic feet per minute. Compressive ventilation is used, the fan, however, is constructed to either exhaust the air from the mine or force it into it. A 7-foot Stine fan ventilates the mine in the upper "Four-foot" seam. Both mines have natural drainage. The gauge of mine-car tracks is 42 inches. The cars used in the lower mine have a capacity of one ton fifteen hundred weight and weigh 1100 pounds when empty. Those used in the upper mine contain one ton four hundred weight and weigh when empty 900 pounds. The mine cars are constructed with four iron bands surrounding the body of the car. Those used in the lower or "Six-foot" bed have double brakes, those of the upper or "Four-foot" seam have single brakes.

THREE FORKS COAL MINING COMPANY.

The Three Forks Coal Mining Company operates a mine known as Three Forks on the Maryland side of the Potomac River two miles northwesterly from Chaffee, the shipping point on the Western Maryland Railroad.

Three Forks mine.—This mine is a drift mine in the Lower Kittanning seam and is reached by a tram-road 9500 feet in length from the

dump to the bottom of a double-track incline plane 540 feet long that leads up to the opening. Like many of the other Maryland operations along the line of the Western Maryland Railroad the coal is taken over a bridge that spans the Potomac River, the tipple being located on the West Virginia side. The coal is hauled over the tram-road by two locomotives, the company having 100 mine cars for transportation purposes. There is an excellent sand rock roof, and the bottom coal is from 54 to 60 inches in thickness, separated by a 12-inch slate binder from the upper bench which is 12 inches thick. The mine is equipped with a fan and now employs 62 men, but this force is to be largely increased. Work on this property was begun in 1906 but the first coal was not shipped until January, 1907. The average daily output is 175 tons but the company is planning to increase this to about 500 tons per day.

HAMILL COAL AND COKE COMPANY.

The Hamill Coal and Coke Company has just completed developments for opening their mine known as Hamill No. 1, three-quarters of a mile east of Blaine Station on the Western Maryland Railroad.

Hamill No. 1.—This is a drift mine in the Lower Kittanning seam and at the close of 1907 had just completed developments preparatory to actual operations. Plans and materials for the plant were furnished by John A. Roebling's Sons Company. The coal is conveyed from the tipple at the pit mouth, across a ravine and the river, to the railroad, a distance of 850 feet with a difference in elevation of 160 feet, by a Roebling twin bucket aerial tramway. This plant operates by gravity, using two buckets each of 2 tons capacity running on 2-inch cables and connected by a $\frac{5}{8}$-inch endless traction rope, which passes around three sheave wheels, each 6 feet in diameter, at the tipple or upper terminal and around two smaller idler sheaves at the lower or discharging terminal. The sheaves at the upper terminal are set horizontally in a triangular shape, the two outside wheels have a brake band around each, which is connected with a lever located in the extreme forward end of the upper terminal, where is also found the two levers for loading the buckets. From this point the entire conveying mechanism is operated by one man.

The main cables are securely anchored in concrete in front of the pit mouth and are suspended the entire distance of 850 feet without support. At the lower terminal they pass over sheave wheels and are kept at an even tension by means of a counter weight of 40 tons attached to the end of each. The buckets discharge automatically into a 50-ton bin at the lower terminal, from which the railroad cars are loaded. The tipple being only 30 feet from the drift, the main heading is of sufficient width for loaded and empty tracks. Fairbanks automatic scales are used, the coal being weighed in the mine car. The plant has a tested capacity of 2 tons per minute.

The railroad siding, which connects with the Western Maryland Railroad, consists of 3200 feet of track, and is made up of 1000 feet of double track connected with a cross-over switch immediately below the terminal. This arrangement permits the placing of empties or the pulling of loads without interference.

THE POTOMAC VALLEY COAL COMPANY.

The Potomac Valley Coal Company operates the Pee Wee or Darwin mine at a point about one mile below Blaine.

Pee Wee or Darwin mine.—This mine is in the Upper Freeport seam, the opening having been made about two years ago. Mules are used for haulage within the mine and the coal reaches the tipple by means of a tram-road 1500 feet in length and an incline 900 feet long. Furnace ventilation is used. The output of the mine is about 200 tons daily. The coal is shipped by the Western Maryland Railroad, the tipple being located on the opposite side of the Potomac River from the mine as in the case of so many of the operations in the Potomac Valley. Forty men were employed on the average during the past year.

THE BLAINE MINING COMPANY AND GARRETT COUNTY COAL AND MINING COMPANY.

The Blaine Mining Company and the Garrett County Coal and Mining Company each own a drift mine in the Lower Kittanning or "Six-foot" seam on the Maryland side of the Potomac River, at Dill, between Blaine

and Harrison, on the Western Maryland Railroad, 19 miles southwest of Westernport. The coal from these mines is run across a bridge over the Potomac River to a double siding on the Western Maryland Railroad

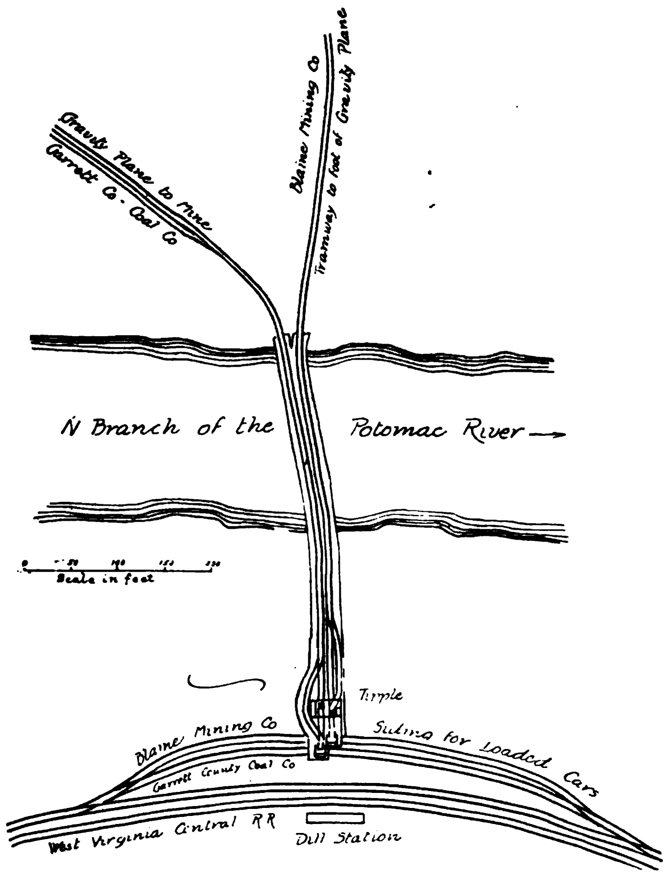

FIG. 14.—Tipples of Blaine Mining Company and Garrett County Coal and Mining Company, at Dill.

on the West Virginia bank. The bridge and tipple, although but one structure serving for the two mines, has double tracks, scales, and dumps so that the output of each can be weighed and loaded into separate cars on the railroad siding. The tipple structure is but 14 feet above the tracks of the railroad siding and has no chutes, the coal being dumped

directly into the railroad cars. The sidings hold eight empty and eight loaded railroad cars for each mine.

The *Blaine Mining Company's mine,* known as the *Blaine mine,* lying about one-third of a mile west of the Potomac River, is connected with this tipple by a gravity plane 1125 feet long and a tram-road 1100 feet in length, the latter being of easy grade and leading from the foot of the plane across the bridge to the tipple on the West Virginia side. At the landing at the foot of the plane the rope is disconnected from the "trip" of four loaded cars and the "trip" is run into the tipple by gravity, controlled by a brakeman. The empty cars are returned to the bottom of

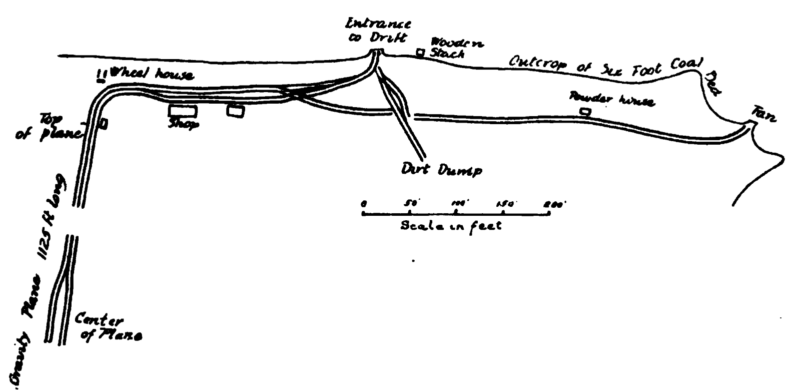

FIG. 15.—Track Arrangement of the Blaine Mining Company.

the plane by a horse and driver. The drift opening is just far enough from the top of the plane to afford trackage room for cars. Sixty men were employed in 1907. The mine is a drift and the coal worked to the rise with entries and rooms in favor of the loaded cars. The haulage is done by horses and the drainage is natural. Some heavy grades are encountered in the workings. The coal bed averages 5 feet in thickness with two slate partings about 1 inch thick dividing the coal bed into three nearly equal benches. The room and pillar system of mining is used. The double parallel entries have pillars 60 feet thick between them. The main heading is 10 feet wide. Branch headings are 16 feet wide and air courses 18 feet. Rooms are driven 18 feet wide and have

pillars of 40 feet between them. The length of the rooms or the distance from one heading to the air courses of the heading is 300 feet.

In the headings 12 to 15 inches of fire-clay rock above the coal bed is taken out and 10 to 12 inches of coal above the fire-clay so that the headings will average 7½ feet in height. The course of the main heading is N. 44° W. That of butt entries to the right is N. 15° E., and of butt entries to the left S. 60° W. The rooms are driven N. 44° W. or parallel to the main entry. The coal is mined entirely by pick-work. The mine is ventilated naturally, assisted by a fan at the drift mouth 100 yards or more northeast of the main opening. The mine cars have a capacity of 1½ tons of coal each and weigh 1200 pounds when empty. They are constructed with three strap-iron binders, and most of them are furnished with double brakes, the bar passing underneath and operating upon both wheels on each side of the car. The gauge of mine-car tracks is 3 feet.

The *Garrett County Coal and Mining Company's mine,* known as *Dill Mine No. 1,* is on the west side of the Potomac River not far from the Blaine mine but has not been in operation since 1904. It is a drift mine in the Lower Kittanning seam and is separated from the Blaine Mining Company's mine by a ravine which has cut out the coal bed and made the two mines distinct operations. A tram-road leads from the drift to the top of the plane which lands the loaded mine cars at the west end of the bridge alongside of the track of the Blaine Mining Company, whence they can be run over the bridge to a tipple by gravity after which they are returned to the bottom of the plane by horses. The plane has three rails and the gauge of the track is 3 feet. The coal bed is worked to the rise and the mine is naturally drained and ventilated.

The Garrett County Coal and Mining Company is at present operating *Dodson mine No. 1,* which is situated at Dodson, about a mile above Harrison, on the Western Maryland Railroad. It is a drift mine in the Lower Kittanning seam, the opening being on the Maryland side of the Potomac River. The mine is operated by tail-rope and mule haulage. There is a plane 700 feet long to the tipple on the Western Maryland Railroad. A second plane 150 feet long leads to an opening 54 feet

above the Lower Kittanning coal, which has been operated at times. The lower opening is provided with a fan, the upper with a furnace. The ventilation is by the overcast system, split in to each heading. The company employed 147 men on the average during the year 1907.

THE UPPER POTOMAC COAL COMPANY.

The Upper Potomac Coal Company operates the Upper Potomac mine near Hubbard on the Western Maryland Railroad.

Upper Potomac mine.—This mine is situated on the Maryland side of the Potomac River opposite Hubbard on the Western Maryland Railroad about midway between Harrison and Schell. The mine is a drift opening in the Lower Kittanning seam. The coal is hauled from the mine by a 4-ton steam locomotive to the head of the gravity plane 1000 feet in length, from which the coal is taken by a bridge over the Potomac River to the tipple, the latter being a plain wooden structure with the short chute dumping endwise into the railroad cars. The mine is naturally drained and is provided with a 12-foot fan. The capacity of the mine is about 300 tons daily. Ninety men were employed on the average during 1907.

THE STOYER RUN COAL COMPANY.

The Stoyer Run Coal Company has three mines, known as Nos. 1, 2, and 3, at Stoyer on the Western Maryland Railroad. Nos. 1 and 3 are the only mines operated at the present time. This property was formerly owned by the Datesman Coal Company, who sold it to John Wills, from whom it was acquired by the Stoyer Run Coal Company in January, 1905.

Mine No. 1.—This mine is located in the Lower Kittanning seam. It is a drift mine, is ventilated by a fan, and is provided with a tram-way to the siding on the Western Maryland Railroad. New mine cars have been recently purchased. This mine now has an output of 300 tons per day. The coal is entirely obtained by hand-pick mining.

Mine No. 3.—This mine is a drift opening in the Upper Freeport seam. A plane about 650 long leads to the upper mine and a small stationary

engine is used to haul the coal out. This mine has a maximum capacity of 300 tons per day.

Forty-three men were employed on the average at this mine during 1907.

THE BEECHWOOD-CUMBERLAND COAL COMPANY.

The Beechwood-Cumberland Coal Company operates the Beechwood mine at Deal on the Western Maryland Railroad. The property is located in Glade Run about 1½ miles east of Gorman.

Beechwood mine.—This mine is a drift opening in the Upper Freeport seam which is about 4 feet 6 inches thick. The main heading and air course have been driven about 1200 feet and rooms turned off to the right and left affording places for 20 miners. The coal is of a good quality with few faults and the partings of bony coal and slate are few and located well apart. The roof and floor are both good, and the mine is fairly dry. The slope of the coal is to the face of the heading and the water is pumped to the pit mouth and discharged into Glade Run.

The cars used in the mine are distributed and collected by mules and brought to the main heading, whence they are drawn out by the stationary engine in the power house. The coal is transported from the pit mouth to the tipple by means of tail rope haulage, over an inclined plane 1800 feet long. The tipple is located on the west bank of the north fork of the Potomac River, and is connected with the tracks of the Western Maryland Railroad by a switch. The tipple is of frame with side dump and scale house. The power house equipment consists of a two-cylinder stationary engine and 100 H. P. boiler.

The production is about 100 tons per day when running full, but the mine has not been operated continuously during 1907. The number of miners employed varies from 10 to 20, and the number of other employees is three, when mining at full capacity.

THE NETHKIN COAL AND COKE COMPANY.

The Nethkin Coal and Coke Company has opened up a mine on the Maryland side of the Potomac River opposite Bayard on the Western Maryland Railroad.

Bayard mine is a drift mine in the Upper Freeport seam. Very little work has been done as yet and the coal thus far has been chiefly furnished for local consumption to the town of Bayard. The mine was idle during the year 1907.

THE PENN-GARRETT COAL COMPANY.

The Penn-Garrett Coal Company operates three small mines, known as Nos. 1, 2, and 3, at Kendall near Friendsville in the Upper Youghiogheny Valley.

Mines Nos. 1, 2, and 3.—The Penn-Garrett Coal Company has opened up three small mines in the Lower Kittanning seam at Kendall about two miles south of Friendsville on the west bank of the Youghiogheny River. An opening has also been made in the "Split-six" seam. The ventilation is natural. The coal is shipped over the Confluence and Oakland branch of the Baltimore and Ohio Railroad. The mines have not been in operation since July, 1907, and the company reports that they are about perfecting the transfer of the property to a new company, known as the Western Maryland Coal and Coke Company. About 10 men on the average were employed in the mine.

THE KENDALL LUMBER COMPANY.

The Kendall Lumber Company operates the Preston mine four miles from Hutton on the Preston Railroad.

Preston mine.—This is a drift mine in the Upper Freeport seam. The mine has natural ventilation through an air-shaft, and the coal is taken from the mouth of the mine to the tipple, a distance of 300 feet, on a tram-road. The coal is shipped over the Preston Railroad to the siding of the Company via the Baltimore and Ohio Railroad at Hutton, although most of the coal is used at the Company's plant. Four men on the average were employed during 1907.

PART III

REPORT ON

THE LIMESTONES OF MARYLAND

WITH SPECIAL REFERENCE TO THEIR USE IN THE MANUFACTURE OF LIME AND CEMENT

BY

EDWARD BENNETT MATHEWS

AND

JOHN SHARSHALL GRASTY

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INTRODUCTION.

Distribution.—Limestone is found widely distributed throughout the Piedmont and Appalachian regions of Maryland, the most important occurrences being in Baltimore, Carroll, Frederick, Washington, and Allegany counties. The floors of the great Frederick and Hagerstown valleys are composed of this rock while many of the smaller valleys, both in the Piedmont and Appalachian regions likewise, are underlain by this material. Marl, which at times has the composition of an impure limestone without the induration which characterizes that rock, is found in several localities in the southern and eastern counties, but nowhere attains sufficient importance to be employed for more than local uses. It is found chiefly in Queen Anne's, Talbot, Calvert, St. Mary's, and Prince George's counties.

Age.—The Maryland limestones vary in age from those that have been assigned to the pre-Cambrian to those of the Carboniferous; the most important being found in the Ordovician, Silurian, and Devonian. The shell marl deposits are chiefly Tertiary, the most important being of Miocene Age.

Origin.—Limestone may be formed either as the result of chemical precipitation from solution or through the accumulation of the shells of organisms that secrete a calcareous test. Most limestones are of organic

origin and have been formed under water, being laid down in the sea at varying depths and at different distances from the shore. Those in Maryland are of marine origin, having been laid down at moderate depths.

Limestones vary both in chemical composition and in physical appearance, the latter often being a criterion of the former. These differences in composition and physical appearance may be due either to differences in the conditions of deposition or to subsequent causes, as for instance, when a limestone from the application of the metamorphic forces, heat and pressure, is changed to a marble. Chemically, the two rocks may be identical, but in one the calcium carbonate is more or less amorphous or perhaps subcrystalline, while in the marble the calcium carbonate is distinctly crystalline, occurring in the form of crystals of calcite in a matrix of calcareous cement. Even more noticeable are the effects due to differences in chemical composition. A limestone deposited under shallow-water conditions and contaminated by land-derived materials is very different both in appearance and in composition from the limestone formed farther off-shore where the water is clearer and deep, and the contaminating impurities such as the suspended material of a muddy sea are probably almost if not entirely absent. In the first case a shaly or argillaceous limestone is formed, while obviously in the latter instance a purer limestone results that is different from the former chemically as well as physically.

COMPOSITION.—The chief constituent of a limestone is calcium carbonate. An absolutely pure limestone contains 56 per cent. CaO (lime) and 44 per cent. CO_2 (carbon dioxide), and its chemical composition is expressed by the formula $CaCO_3$ (calcium carbonate). Most limestones are contaminated, however, by the presence of other constituents such as magnesia, silica, iron, and alumina; and though there occur workable deposits of very pure limestone whose composition closely approximates that of the ideal as expressed by the formula just given, they are very rare, and because of their scarcity, when well situated for commercial use, are each year becoming increasingly valuable, chiefly because of the growing demand and the necessity of their use in certain metallurgical processes and for other purposes where the purity of the limestone is the

chief essential. It must not be inferred, however, that only the pure limestones are valuable. Often the constituents that cause their impurities give the impure limestones a value for special use, as, for instance, the argillaceous impurities of some of the limestones give them a special value when used in the manufacture of cement. Magnesia, the bane of the Portland cement manufacturer, is one of the chief impurities found in limestones of nearly all geological horizons, but aside from a few notable exceptions, especially is this true of the older limestones. When the magnesia approximates to 21.73 per cent. and the lime 30.44 per cent., with 47.83 CO_2, the stone so composed is known as a dolomitic. The presence of the magnesium carbonate, though an impurity, unaccompanied by appreciable quantities of the impurities, silica and alumina, renders limestone so constituted adapted for fluxing purposes. It must be evident, therefore, that the value of a limestone may not depend altogether on its purity, but may be equally as valuable because of the lack of it. It is not customary to describe the rock as a limestone when the magnesia is over 21 per cent., or when the sum of the silica, alumina, and iron is more than 36 per cent. The former would be called a dolomite and the latter a calcareous shale.

VARIETIES.—Limestones differ widely in color, texture, and chemical composition. In color limestones range all the way from white to black, depending upon differences in texture and composition. The so-called amorphous limestones generally appear light gray to bluish-gray, weathering light gray to dove-colored and less commonly brown. With increasing crystallinity the color becomes brighter and often white. Crystalline varieties occur which are variegated in color due to microscopic coloring matter or to the presence of colored minerals resulting from the crystallization of original impurities. The color may be uniformly distributed throughout the mass, arranged in definite bands, or disseminated irregularly. In texture they may be massive or laminated, clearly crystalline or apparently amorphous. In chemical composition they may be pure, highly magnesian and dolomitic, or argillaceous, due to clayey impurities with wide ranges in the content of iron, silica and alumina. Marked differences occur not only in the respects just mentioned, but also in the

degree of hardness and in the manner of weathering and fracture. According to the various characteristics, limestones may be described as argillaceous, silicious, bituminous, magnesian; massive, flaggy, or oolitic; chalky, shelly, or coralline. Moreover, a limestone may range, depending on the absence or the degree of metamorphism, from an amorphous limestone to one highly and coarsely crystalline, and in the latter event is properly termed a marble. Many coarsely crystalline limestones, however, are not referred to as marbles because of their not being adapted to purposes for which marble is commonly used, though in a scientific sense they may be true marbles.

USES OF LIMESTONE.

Limestone has a wide range of uses and is easily the most thoroughly exploited of all the sedimentary rocks. Besides yielding the most fertile soils it furnishes the basis of a number of extremely important industries, notably those of cement and lime. Millions of tons are quarried and used in the metallurgy of iron while thousands of tons are also consumed annually by the lead- and copper-smelting industries. As is well known, limestone is extensively employed and much in demand as a building stone and used as a road metal and as ballast and in concrete work, and for a large number of miscellaneous purposes less important which it is unnecessary to enumerate here. The four major uses of limestone are:

1. Building stone.
2. Crushed stone.
3. Metallurgical uses.
4. Limes and cements.

These uses will be taken up and discussed in the order in which they are mentioned.

BUILDING STONE.*

The chief limestones quarried in Maryland and shipped for building stone are the white crystalline varieties; in other words the limestone

* The Building and Decorative Stones of Maryland. Md. Geol. Survey, Vol. II. Pt. II.

found in the eastern and western Piedmont which have been metamorphosed to marbles. The blue and gray Paleozoic limestones that occupy the Hagerstown and Frederick valleys are quarried for local use, but there is no quarry in operation either in the Hagerstown or the Frederick valleys making it a business to furnish these blue-gray limestones for building purposes alone. Since these limestones at certain horizons furnish stone of excellent quality for structural work it is surprising that they are not more widely used for building purposes. A marble resulting from the local metamorphism of the Tomstown formation of the Shenandoah group has, however, been quarried extensively near Eakles Mills, Washington County. The blue and gray limestones are also widely used for minor building purposes, such as trimming, door sills and foundations, although it is noteworthy that few buildings either in Hagerstown, Frederick, or the surrounding towns have been built exclusively of limestone during later years. In the area between North Mountain and the western boundary of the State Paleozoic limestone formations of later geological age occur, namely, the Cayuga, the Helderberg, and the Greenbrier, but none of these has more than a very limited use as a source of building stone. Of the limestone formations mentioned the Helderberg is the only one which offers reasonable grounds for expecting good building material within its limits. The upper massive beds of the Helderberg, which outcrop in five or six small bodies along the Potomac from Hancock to Cumberland, and form a continuous belt from the latter point to Keyser, West Virginia, afford every indication that satisfactory building stone may be obtained. Little if any work has been done in this formation because there has been no local demand.

CRUSHED STONE.

Limestone is sold in the form of crushed stone to be used as road metal, ballast, and for concrete work. The size of the fragment in each case will depend upon the use for which it is employed. The statistics gathered by the Maryland Geological Survey, in conjunction with the United States Geological Survey, show that limestone sold as crushed stone in

Maryland has a much greater value as regards the annual production than any other crude form in which it is marketed. All three types as enumerated above are obtained from crushing the stone as delivered from the quarry either in Austin or Gates crushers or other suitable machinery, then passing it for assortment into sizes through inclined rotary screens. The "screenings" or smallest sizes are being further pulverized by certain operators in various parts of the country to meet a growing demand for ground limestone for use as a soil amendent.

ROAD METAL.*—The limestone for road metal should possess high-cementing power and high resistance to wear. The first property indicates the consolidation of surface dust after rains and a satisfactory cementation of the smaller fragments of the upper course of the road. The high-cementing power usually possessed by limestones offsets in great measure their lower coefficient of wear when compared with trap and other road metals. Crushed limestone for road work is usually assumed to have good cementing values without special testing, but the coefficient of wear must not be less than 12, the cementing power increasing with the purity of the limestone, the wearing ability with an increase of silica.

Most of the limestones in the State are locally serviceable for road metal, but material for high-class construction is more or less limited.

BALLAST.—Crushed limestone is used extensively for ballast in railroad construction because of the angular forms into which the fragments break and the freedom from serious breaking when tamped under the sleepers. Heretofore limestone has been regarded as one of the most satisfactory and economical ballast materials, but with the increase in the weight of rolling stock and the severe demands on the roadbed there has developed the beginning of a demand for stone of higher crushing strength, even if more expensive. This change in demand may lead to the utilization of highly silicious limestone and calcareous sandstone which hitherto have been practically worthless.

CONCRETE.—Stone crushed for use in concrete should be free from large amounts of dust and not too closely screened to uniform size in

* Md. Geol. Survey, Vol. III, pp. 315-330; Vol. IV, pp. 124-133.

the smaller sizes since experiments have shown that the strongest cement mortars are those in which there is the greatest density due to the close packing of different sized fragments which leaves the lowest percentage of voids or cavities. It should be borne in mind that the strength of the stone has an equal if not greater influence on concretes for certain uses, but the relative influence of the size, shape, and strength of the stone fragments has not been finally determined.

GROUND LIMESTONE.—Inasmuch as this ground limestone may be applied at any season of the year, and is said to yield excellent results when ground to a fineness of 60 to 70 mesh, there are those that hold the opinion that it is destined to be largely used as a substitute for burnt lime for agricultural purposes.

The liming of the soils with burnt lime has long been known to effect a " sweetening " of soils which have become " soured." The recent work on the part of agriculturalists and soil bacteriologists has shown that the so-called sour condition of the soil, resulting in a decrease in the second crop of a given cereal, is due more to the toxic condition of the soil through secretions of the vegetation than to an actual lack of plant food. It was also formerly supposed that the liming of the soils not only neutralized the acidity of the soil, but furnished the plant food. When lime ($CaOH_2$) is added to the soil it gradually changes under the action of the atmosphere and moisture of the soil to carbonate of lime which to some extent is converted through excess of carbon dioxide to soluble bicarbonate or acid carbonate of lime. The use of ground limestone is based upon the assumption that since it is carbonate of lime it will prove as satisfactory as agricultural lime provided the two are of the same degree of fineness. It is a well-known fact that the chemical activity varies with the fineness of the grain on account of the relatively large surface of the individual particles as compared with their mass. The problem for the manufacturer is to establish a balance between the decrease of efficiency due to coarseness of grain and the increase in cost due to excessively fine grinding.

Crushed limestone, or better ground limestone, is now used in enormous quantities in the manufacture of calcium nitrate for use as a ferti-

lizer. The possibility of making a cheap calcium nitrate by treating either calcium carbonate or lime with nitric acid depends upon the cost of the latter reagent. By the introduction of new electrical processes the reduction of cost of nitric acid has been sufficient to render the profitable manufacture of calcium nitrate feasible.

Ground limestone is also used for neutralizing the acidic condition of dyed textiles and in the manufacture of carbon dioxide by the treatment of limestone with acid.

METALLURGICAL USES.

The uses of limestone, including in that term also the dolomites and dolomitic limestones, will depend in general upon its chemical composition, and more particularly upon its freedom from siliceous impurities. The more important uses in the approximate order of purity of stone required are as follows:

1. Glass-making.
2. Furnace linings.
3. Flux in blast furnaces.
4. Flux in basic open hearth steel furnaces.
5. Cement manufacture

Of these uses only 2, 3, and 4 can properly be termed metallurgical uses.

Glass-Making.

Limestone enters as an essential element into the manufacture of glass. In plate glass it equals about one-quarter by weight of the sand in the batch, and in window glass about two-fifths, while in green-bottle glass the proportion by weight compared with the sand is about one-third. The other essential raw materials that enter into mixtures for manufacturing glass are salt cake (Na_2SO_4) and soda ash (Na_2CO_3). Carbon (C), arsenic (As_2O_3), potash (K_2CO_3), and red lead (2Pb-O, PbO_2), are also used in small amounts. Sand constitutes 52 to 65 per cent. of the mixture of raw materials. After this mixture has been melted and carbon dioxide, sulphur dioxide, and other

volatile compounds have been driven off the finished product contains from 60 to 75 per cent. of silica.

Limestone used in glass-making should contain very little ferric oxide and very little magnesia. The former should not exceed .5 to .6 per cent. —the less the better, since the effect of iron in greater amounts than .5 to .6 per cent. is injurious because it detracts from the brilliancy, clearness, and transparency of the finished product. Magnesia is an undesirable constituent, for with it present in the mixture of raw materials more heat is required to produce fusion and form the silicates of sodium, potash, calcium, etc., of which glass is composed, than would otherwise be necessary.

The following analyses give the composition of limestones actually used in glass manufacture. The analyses of limestone is followed by an analysis showing the composition of a typical good glass-sand. A comparison of these limestone analyses with those of some of the limestone material near Union Bridge, and with certain of the limestone occurrences in the eastern Piedmont and elsewhere in the State, shows that limestones of a correct composition for glass-making may be had in Maryland at a number of different localities.

ANALYSES OF LIMESTONE AND SAND USED IN GLASS-MAKING.*

	Limestone.				Sand.
	1	2	3	4	5
Silica (SiO_2)†	8.87	1.86	1.01	1.01	98.94
Alumina (Al_2O_3)	....	....	1.10	.02	.30
Iron (Fe_2O_3)	.59	....	.20	.16‡	.0036
Magnesia (MgO)	.00	.09	....	.72	Tr.
Lime (CaO)	50.53	54.86	54.73	54.45	.40
CO_2	39.70	42.89	42.99	43.55	.23

1. Meramec Quarry Co., Wickes, Mo.
2. Meramec Quarry Co., Wickes, Mo.
3. Armstrong Quarry, Alton, Ill.
4. Pennsylvania., Cf. Mineral Industry, 1899, p. 240.
5. Analysis of Glass-Sand used by Pittsburg Plate Glass Co.

* Burchard, E. F., U. S. G. S. Bull., 285, p. 458.

† Including silicates.

‡ $FeCO_3$.

Furnace Linings.

Dolomite and dolomitic limestone is much used as a material for lining basic open-hearth furnaces. The tonnage required for this purpose is, of course, comparatively small, but nevertheless, the use is an important one and requires a stone of high quality.

A brief description of the method of making up these linings seems necessary here. The substructure of the furnace having been built up of common red brick, a permanent lining of basic brick, usually magnesite brick, is built in to a thickness of from 2 to 3 feet. On this is then tamped a working lining of crushed basic material, sometimes magnesite, but now generally dolomite or a mixture of the two. In the older practice it was considered necessary to first calcine the crushed material to drive off the carbon dioxide; it was then mixed with a small percentage of tar or molasses and tamped into place to a thickness of 1 or 2 feet. At present the preliminary calcination is quite generally omitted, satisfactory results being obtained by calcination in place of the raw material mixed with the proper proportion of binder.

From a purely technical standpoint the ideal material for both permanent and working linings is magnesite, and only the excessive cost of this prevents its more extensive employment. While magnesite is known to occur at numerous points in this country, it is only produced commercially in California, and by far the greater proportion of our supply is imported from Greece and Austria. Dolomite, on the other hand, is found in great abundance and of great purity in this country, and hence has largely superseded the more expensive magnesite.

The essential properties of a satisfactory open-hearth furnace lining may be stated as follows:

1. It must be refractory at the highest temperature of the furnace.

2. It must be resistant to the corrosive action of slag and metal.

3. It must not slack or otherwise disintegrate when the furnace is cooled down.

4. It must not crack when heated.

5. It must have sufficient mechanical strength to withstand the swash of the liquid masses in the furnace.

6. It must be fairly cheap.

To meet conditions 1 and 2 the stone must be rather pure, that is, free from silica and alumina, substances which act as acids to the bases of the stone, and by the formation of fusible compounds lessen its refractoriness.

To meet condition 3 a stone high in magnesia is necessary. Pure magnesite after calcination will only slake (or combine with water with the formation of a hydrate and consequent expansion and disintegration) with exceeding difficulty. Lime, on the other hand, slakes very rapidly, and hence gives a lining of poor durability. Calcined dolomite stands between lime and magnesite in this respect and, therefore, cost considered, makes the most satisfactory lining.

A stone suitable for lining basic open-hearth furnaces should fill the following specifications as to composition:

	Per cent.
Silica (SiO_2) under	1.00
Aluminum and Iron Oxides (Al_2O_3, Fe_2O_3) under	1.50
Magnesium Carbonate ($MgCO_3$)	35.00
Calcium Carbonate ($CaCO_3$)	65.00

The more nearly the stone approaches magnesite ($MgCO_3$) the better. Dolomite and well-burned dolomitic limestone are more extensively used than magnesite because they are cheaper.

Analyses of limestones in actual use are as follows:

	Silica.	Iron and alumina.	Lime (CaO).	Magnesia (MgO).	Loss on ignition.
1. Dolomite	0.60	0.78	31.52	20.21	47.10
2. Same, Burnt	1.00	1.80	64.48	32.16	0.56
3. Dolomite	1.11	1.35	30.67	20.45	....
4. Dolomite	0.72	0.99	31.15	20.36	....

Nos. 1 and 2 furnished by courtesy of Mr. G. F. Albrandt, Am. Rolling Mill Co.

Nos. 3 and 4 are limestones used by the Illinois Steel Co.

*Blast-Furnace Flux.**

A very large and important use of limestone is as flux in the iron-blast furnaces of the country. Approximately one-fourth of the total amount of stone quarried is used for this purpose, and according to the statistics of the U. S. Geological Survey 17,119,297 tons were thus consumed in 1907.

The value of a limestone as a blast-furnace flux is dependent on the following factors:

1. Physical condition, i. e., freedom from dust.
2. Purity, with respect to silica and alumina.
3. Purity, with respect to sulphur and phosphorus.
4. Proportions of lime and magnesia.

The factor of physical condition is of but minor importance, and in the vast majority of cases needs but slight consideration. It is only in the case of such materials as marl and travertine that dusting becomes serious, and with ordinary limestones the variations in amount of dust formed are inconsiderable and unimportant.

The chemical composition of limestone is, on the other hand, of the utmost importance, and in particular is this true † with respect to its content of silica and alumina. As the function of the limestone in the blast furnace is to furnish bases (lime and magnesia) to combine with and flux the acidic impurities in ore and coke, it is evident that its efficiency for this purpose will decrease very rapidly with increase in acidic impurities in the limestone itself.

This decrease in available bases may be readily calculated, provided we assume a definite ratio of bases to acids in the blast furnace slag. In practice this ratio is not definite but varies, not only with the kind of iron which is being made, but even from day to day in the same furnace. However, the amount of variation is not great, and if technical and com-

* The writers are indebted to John J. Porter, Associate Professor of Metallurgy at the University of Cincinnati, for the Analyses and Metallurgical formulas, employed in the use of limestone as a flux, etc., given in this report in the following discussion.

† Campbell, "The Manufacture and Properties of Iron and Steel," p. 190.

mercial, rather than scientific results are desired, are absolutely unimportant. By the inspection of a very large number of slag analyses, representing all sections of the country and all grades of iron, the ratio of 1:1, or lime plus magnesia divided by silica plus alumina equals 1, has been determined as a fair average value, and this value is used in the following calculations.

Let A be the per cent. of acids (Silica plus Alumina) in the stone. Then to flux these acids A per cent. of lime plus magnesia will be required, and $2A$ per cent. of slag will be formed. To convert lime into lime carbonate (CaO to $CaCO_3$) the factor is 1.785, while if the stone is pure dolomite containing 40 per cent. of $MgCO_3$, the factor becomes 1.911. As most fluxing stone runs under 10 per cent. in $MgCO_3$ it will be better to take this conversion factor as 1.8. This gives the percentage of carbonates utilized in fluxing the impurities in the stone itself, as $1.8A$ per cent., wherefore the percentage of carbonates in the stone available for fluxing extraneous material is $100-(A+1.8A)$, or the "available carbonates" equal $100-2.8A$ per cent. This assumes that the limestone is composed entirely of $CaCO_3$, $MgCO_3$, SiO_2, and Al_2O_3, which, while not strictly true, is practically so, since all other constituents seldom total as high as 1 per cent.

Sulphur and phosphorus are usually present in limestone in minute amounts, but it is but seldom that their presence need cause concern.

Sulphur will certainly do no damage if not in excess of 0.5 per cent., and can probably be present in much larger amounts before its bad effects will become distinctly recognizable. It is very unusual to find over 0.1 per cent. in limestone.

Phosphorus is only important if the stone is to be used in the manufacture of bessemer iron. In this case it becomes highly important and should not exceed 0.01 per cent., preferably being even lower. In making other grades of iron, phosphorus in the stone would have to reach at least 0.1 per cent. in order to deserve consideration, whereas, as a matter of fact, it is exceedingly rare to find it even as high as 0.05 per cent.

The relative amount of lime and magnesia in the stone is also important, but in the present state of our knowledge it is next to impossible

to make any but the most general statements as to the proportions most to be desired.

The smaller atomic weight of magnesium (40 as compared with 56 for calcium) enables it to combine with a larger proportion of acids than calcium to form a slag of a given formula. For example, $MgSiO_3$ consists of 40 per cent. MgO and 60 per cent. SiO_2; while $CaSiO_3$ consists of 48.28 per cent. CaO and 51.72 per cent. SiO_2. This is almost exactly offset by the smaller percentage of MgO in $MgCO_3$, 47.62, as compared with 56 per cent. CaO in $CaCO_3$. One pound of $MgCO_3$ will convert .2867 pounds of SiO_2 to $MgSiO_3$, whereas 1 pound of $CaCO_3$ will convert .2896 pounds of SiO_2 to $CaSiO_3$.

The specific heat of magnesia is considerably greater than that of lime (.224 as against .174). Hence the specific heat of magnesia slags is somewhat higher than in the case of lime slags, and slightly greater quantities of fuel are required to melt them.

Again, magnesia has less * affinity for sulphur than lime, the molecular heats of formation of magnesium sulphide and calcium sulphide being 79,400 and 94,300 calories, respectively. This means that a magnesia slag is less efficient in removing sulphur than a lime slag, and that, other things being equal, a more basic slag will be needed in the case of dolomite than if all limestone were used. It should, perhaps, be explained that the term "a more basic slag" is used in its strict chemical significance, and does not necessarily mean a higher percentage of magnesia. For example, suppose the normal slag to be $CaSiO_3$, containing 48.28 per cent. of CaO, then the magnesia slag of corresponding basicity is $MgSiO_3$, containing only 40 per cent. of MgO. As explained above, however, the amounts of the carbonates required to produce slags of equal basicity are the same in either case, and hence for the efficient removal of sulphur more magnesian stone will be required than in the case of purer limestone.

Practical experience in the use of dolomite containing 40 per cent. of $MgCO_3$ indicates that the fuel consumption is not invariably higher in spite of the unfavorable factors enumerated above. This is probably due

* Hofman, Iron and Steel.

to the fact that most magnesian slags are, when molten, more fluid than the corresponding lime slags. This, in many cases, results in better and more regular working of the furnace, thus indirectly accomplishing a counterbalancing saving in fuel.

It is quite evident from what has been said on this subject that our present knowledge of the quantitative effect of magnesia is very meager, and that it is impractical to consider it in any numerical comparison of the relative values of limestones.

The derivation of a rational formula or rule for the exact valuation of limestones used as furnace flux is of great practical importance, and will be attempted here. There are so many variable factors which in one way or another enter into such calculation that it is obviously impossible to take them all into account and obtain a scientifically exact formula of universal applicability. Fortunately, however, many of these factors vary but slightly from an average value, and moreover have but a slight quantitative effect upon the final results of our calculation. It is, therefore, entirely satisfactory from a practical standpoint to use these average values in deriving a formula which will be a suitable guide in estimating the value of stone.

As will have been gathered from the preceding discussion, it is necessary to base these calculations entirely on the silica and alumina contents of the stone. The effect of physical condition, magnesia, sulphur, and phosphorus are as a rule *nil*, and in the exceptional cases where they do effect the value the amount is incapable of being determined by any generally applicable rule.

The causes of the decrease in value of a limestone with the increase in per cent. of impurities may be summarized as follows:

1. Lower percentage of available bases.
2. Cost of coke to melt the extra slag formed.
3. Increase in manufacturing cost due to decreased output.

The first of these factors, the lower percentage of available bases, has already been discussed, and it was found that in any impure stone the available carbonates $=(100-2.8A)$ per cent., where A is the per cent. of silica plus alumina in the stone.

The weight of coke necessary to care for the slag formed from the impurities in the stone is evidently equal to the weight of slag formed times the weight of coke necessary to melt a unit of slag. As this weight of slag is $2A$ per cent. of the weight of stone used, the extra coke required per ton of stone is equal to $2A/100$ times the weight of coke required per ton of slag.

This weight of coke per unit of slag may be calculated from several standpoints, as, for example, by the use of the principal of critical temperatures, from the heat-balance sheet of the blast furnace, and empirically from the results of practice. The calculations are very lengthy and involved, and the results depend upon the magnitude of many variable factors, such as the fusion point of the slag, the specific heat of the slag, the temperature of the blast, the per cent. of the carbon reaching the tuyeres, the per cent. of moisture in the blast, etc., etc. In order to get an answer it is necessary to give values to these factors, and this has been done, selecting average values applicable to Northern and Eastern practice. The resulting answer comes out .136 and .138 pounds of carbon per pound of slag by two theoretical methods, and .128 if worked out empirically from the results of practice. There is, therefore, assumed a carbon consumption of .13 pounds per pound of slag to be melted, or .1456 short tons of carbon per long ton of slag. The figures would be considerably greater for Alabama practice, but for Northern practice this value is believed to be safe and conservative.

If C stands for the extra coke, in short tons, required per long ton of stone; P be the price of this coke per short ton; fc be the per cent. of fixed carbon in the coke; and A, as before, the per cent. of acidic impurities in the stone, then $C = 2A \times .1456/fc$. Adding 5 per cent. for breeze or waste coke, $C = 306A/fc$. While the cost of the coke to care for the impurities in one long ton of stone $= \frac{.306AP}{fc}$.

The manufacturing cost is also influenced by the impurity of the stone through the decreased output which is caused by impure stone, the output with any given ores and rate of driving being inversely proportional to the coke charged. That is, with a given volume of air blown

per unit time a given amount of coke will be burned per unit time, hence the larger the amount of ore accompanying this coke, or in other words the less the proportion of coke in the charge, the greater the output; or the output is inversely proportional to the coke consumption.

Let M = Manufacturing cost per ton of iron, pure stone basis.
C = Short tons of coke to care for impurities in one long ton of stone.
I = Increase in manufacturing cost per long ton of stone due to impurities.
S = Long tons of pure stone needed per ton of iron.
Ck = Short tons of coke used per ton of iron, pure stone basis.
A = Per cent. of silica plus alumina in stone.
P = Price of coke per short ton.
fc = Per cent. of fixed carbon in coke.
V = Value of pure stone.
V' = Value of impure stone.

Since the manufacturing costs per day are practically constant, the costs per ton of iron are equal to a constant divided by the output, or $M : 1/\text{output}$.

But it has already been shown that the output is inversely proportional to the coke consumption, and, therefore, $M : Ck$, and also $M/S : Ck/S$.

In the case of the impure stone the manufacturing cost per ton of stone is $M/S+I$, and the coke used per ton of stone is $Ck/S+C$. Therefore,

$$\frac{M}{S} : \frac{M}{S}+I :: \frac{Ck}{S} : \frac{Ck}{S}+C.$$

From this we get $I = MC/Ck$, or as C has already been found to equal $.306A/fc$, we have $I = .306MA/fc.\,Ck$.

By combining these expressions for each of the three factors affecting the value of any impure stone, an expression may be obtained for the value of the stone as follows:

$$V' = V(1.-.028A) - \frac{.306AP}{fc} - \frac{.306MA}{fc.Ck},$$

or condensing

$$V' = V(1.-.028A) - \frac{.306A}{fc.}\left(P - \frac{M}{Ck}\right),$$

and from this expression, or from the constituent factors considered separately, it is easy to obtain absolute or relative values for any stone in any form desired.

Many furnace managers are losing money in buying stone, either by indifference and lack of knowledge as to the quality of the stone they are using, or through actually preferring a more impure stone at a few cents less cost per ton. Other more progressive managers realize fully the importance of the question, and insist on the highest obtainable quality of stone. The accompanying diagram (Fig. 16) shows graphically how serious is the effect of acidic impurities on the value of a fluxing stone, and will probably be a revelation to many persons.

Because of the fact that it is possible to use an impure stone, even up to 8 per cent. of silica plus alumina, and because commercial exigencies sometimes force the use of such stones, it is practically impossible to formulate a universally applicable specification for blast-furnace fluxing stone, although this may readily be done for any particular furnace or district. The following table gives analyses of fluxing stones actually in use at representative plants in various sections of the country, and will show far better than any specifications the range of composition permissible:

ANALYSES OF LIMESTONES USED FOR BLAST FURNACE FLUX.

District.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron Oxide (Fe_2O_3).	Lime Carbonate ($CaCO_3$).	Magnesia Carbonate ($MgCO_3$).	Cost per ton, f.o.b. furnace.
Alabama	3.78	2.44	0.75	86.26	7.05	0.65
"	1.62	0.70	0.30	54.20	43.18	..
Canada	1.81	0.90	..	93.22	1.56	..
"	1.70	0.38	..	93.33	3.99	..
Illinois	1.93	1.29	1.10	94.20	1.10	..
"	1.01	0.99	0.40	54.88	42.76	..
Pennsylvania ..	6.50	2.05	0.45	88.00	3.00	0.70
" ..	3.90	1.88	0.52	92.20	1.50	0.80
" ..	0.90	0.48	0.20	97.26	1.05	..
Virginia	6.00	3.50	0.50	86.00	4.00	0.70
"	4.30	2.00	0.20	90.00	3.36	0.75
"	0.42	1.20	0.30	54.08	43.86	0.65

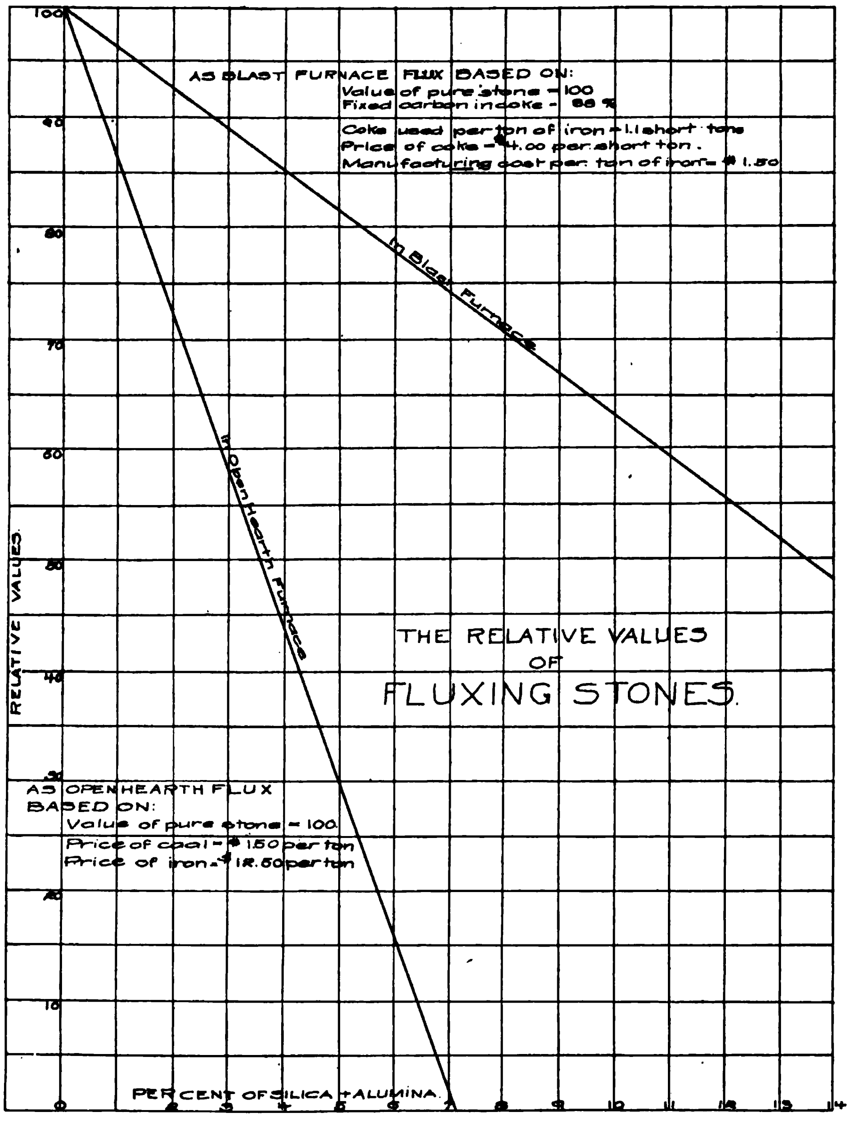

FIG. 16.—Diagram showing relative values of fluxing stones.

Basic Open-Hearth Furnace Flux.

The function of limestone in the basic open-hearth steel furnace is quite similar to its function in the blast furnace. That is, it is used to flux the silica and alumina present. The value, therefore, is dependent on the same factors as in the case of the blast furnace, but as the conditions are quantitatively different, so also the values of these factors are different.

As to physical condition, the freedom from dust is of rather more importance than in the case of the blast furnace, any dust being carried over into the checkers and causing these to deteriorate very rapidly. However, no great trouble is experienced with ordinary stones in this respect, and the factor is of very minor importance.

The purity, with respect to lime and magnesia, is, as before, the important point, but even more so now than in the case of the blast furnace. In the basic open-hearth furnace, because of the necessity of removing phosphorus and preventing the cutting out of the basic lining, it is necessary to carry an exceedingly basic slag, the usual limits and average composition of which are about as follows:

AVERAGE COMPOSITION OF BASIC OPEN-HEARTH FLUX.

	Maximum.	Minimum.	Average.
Silica (SiO_2)	25.00	10.00	17.00
Alumina (Al_2O_3)	6.00	1.00	3.00
Iron Oxide (Fe_2O_3).........	25.00	10.00	19.00
Manganese Oxide (MnO)...	15.00	3.00	6.00
Lime (CaO)	50.00	35.00	44.00
Magnesia (MgO)	10.00	4.00	6.00
Phosphoric Acid (P_2O_5)....	15.00	2.00	5.00

In this case it is seen that the average ratio of lime plus magnesia to silica plus alumina is 50/20 or 2.5, so that we have: Bases necessary to flux the acids in the stone equals $2.5A$, or carbonates equals 1.8 by $2.5A$, and the percentage of available carbonates in the stone$=100-1.8\times 2.5A$, or $=100-4.5A$.

Sulphur and phosphorus are here again of but minor importance. Sulphur should not exceed 0.5 per cent., and phosphorus 0.1 per cent.,

but as these impurities seldom reach these limits in commercial stones it is rarely necessary to consider them.

The relative proportions of lime and magnesia need some consideration. A high percentage of magnesia is not desired in the slag, as it has a poorer affinity for sulphur and phosphorus than the lime which it replaces. However, magnesia in the form of dolomite is desired for patching bottoms, as described under the head of furnace linings, and used in this way portions of it dissolve in the slag, so that it becomes a flux as well as a lining. We may, therefore, value the stone used for lining as though it were a flux, counting magnesia as equivalent to lime, but in the flux proper it is desirable to hold the magnesia as low as possible.

The derivation of a rational formula for the valuation of limestones used in basic open-hearth practice is subject to the same difficulties as in the case of the blast furnace, and is gone about in the same way. The causes of the decrease in value with increasing impurities are practically the same, as follows:

1. Lower percentage of available bases.
2. Cost of fuel to care for extra slag formed.
3. Increase in manufacturing cost due to decreased output.
4. Value of iron lost in slag.

The lower percentage of available bases has already been considered and the percentage of available carbonates was found to be $100-4.5A$.

The cost of fuel to melt the extra slag formed is, of course, equal to the weight of slag times the weight of fuel to melt a unit of slag times the cost of fuel. The weight of slag is equal to $.05A$ (see average analyses above). The fuel to melt the slag is more difficult to calculate. There is but little published data on the subject on which to base calculations, and, as in the case of the blast furnace, the exact calculation involves innumerable variables. However, based on average practice we may assume the following conditions:

Coal used contains 8000 pound calories per pound.

Fifty per cent. of the heat generated by the coal is absorbed in one way or another in the furnace proper.

Total heat in 1 pound of molten slag equals 500 pound calories.

We have, now, pounds of coal used per pound of slag formed equals: Heat in 1 pound of slag, plus Heat to decompose carbonates represented by 1 pound of slag, divided by Calorific value of coal, times .50, or =

$$\frac{500+.44\times451+.06\times350}{8000\times.5}=.18 \text{ pounds.}$$

And, Cost of coal to care for extra slag formed $=.18\times.05A\times$ Price coal per ton $=.009AP$.

The increase in manufacturing cost due to impurities is caused in two ways.

Referring to the table of slag analyses it will be seen that each pound of slag retains on the average .19 pounds of iron oxide, equal to $.19\times 56/72$, or .14 pounds of iron, and the output may be regarded as being decreased by this much for every pound of slag present. This decrease in output is then one source of the increase in manufacturing cost.

Again, a given amount of heat supplied to the furnace may be regarded as producing a certain weight of steel under any given set of conditions. If now one of these conditions is altered, i. e., the amount of slag present is increased, some of the heat will be required to care for this slag, less will be available for the production of steel. and if the heat supplied per unit time be constant, the output per unit time will be decreased. This is the second source of increase in manufacturing cost.

Both of these items come out practically *nil* under all ordinary conditions of practice, but the expressions are given here, chiefly as a matter of interest. They are readily derived in a manner similar to that used in the case of the blast-furnace calculations, only assuming that 600 pounds of coal are used per ton of steel produced.

Increase in manufacturing cost from decreased output due to loss of iron in extra slag $=M\left(\frac{.007SA}{1-.007SA}\right)$.

Increase in manufacturing cost due to heat consumption of extra slag

$$=M\left(\frac{36.A}{2{,}400{,}000-36.AS}\right).$$

Where M is Manufacturing cost per ton of steel, pure stone basis.

S is Tons of stone used per ton of steel.

A is Percentage of silica plus alumina in stone.

Coming now to the last item, value of iron lost in extra slag formed, this is equal to: Weight of slag per ton of stone, times the per cent. of iron in slag, times cost of iron; and this expression reduces to $.007AP'$, where P' is the price of iron (pig iron or scrap) used, per ton.

Finally, the expression for the value of any impure stone, neglecting increase in manufacturing cost as unimportant, becomes $V' = V(1.00 - .045A) - .009AP - .007AP'$. The symbols used having the same meaning as before.

On the diagram (Fig. 16) the lower line shows how rapidly the value falls off as the impurities increase. This rapid decrease in value is well recognized by practical steel men, who, therefore, insist on the very highest grade of stone for this purpose. Specifications usually run about this way:

	Per cent.
Silica, under	1.00
Alumina, under	1.50
Magnesia, under	5.00

while analyses of stones actually in use are as follows:

	Ohio.	Illinois.	Pennsylvania.
SiO_2	0.68	1.15	.94
Al_2O_3	1.53	.81	.82
Fe_2O_3	0.47	.40	.64
$CaCO_3$	93.86	97.07	94.73
$MgCO_3$	4.22	.50	2.97
	100.76	99.93	100.10

LIMES AND CEMENTS.

When natural limestones are "burned," i. e., heated to a temperature of 925° C., the chemical union of the constituents is broken down and the gaseous CO_2 is driven off. The remaining substance, CaO, possesses properties quite different from the original stone which makes the mass available for many purposes. These properties depend upon the methods of treatment employed and the character and amounts of the impurities contained in the original rock. The products likewise differ. By suitable processes the limestone by itself may be changed to caustic, hydrated,

or hydraulic limes or to natural cements. By the addition to the limestone, before burning, of certain necessary materials in proper proportions the product may be Portland cement. The following pages will include a full discussion of the methods of burning and the resulting products, including limes, natural, and Portland cements.

BURNING OF THE LIMESTONE.

The fact that limestones when burned lose part of their constituents and acquire new and valuable properties was known by the ancients, and from their day to the present limestones have been burned in various ways from the crude heaps of wood and stone of the pioneers to the more complicated and permanent continuous kilns of the cement manufacturers.

The kilns in which the limestone, shell, or marl is burned differ widely. The crudest method of burning consists in arranging a pile of logs and limestone so as to admit air freely to facilitate the burning of the fuel with the limestone, or whatever raw material may be used.

The types of kilns employed in lime-burning vary both in form and construction all the way from the crude type just mentioned to kilns built of solid masonry or constructed of boiler plate and lined on the inside with fire-brick. The different types that are in use may be grouped under two main classes:

Intermittent kilns.

Continuous kilns.

Intermittent Kilns.

This type of kiln is one of the more primitive employed, and since each burning of a charge constitutes a separate operation it is equally as un-economical as it is primitive. There is a great waste of heat. After the kiln is charged and burned the operator must wait for it to cool. When it has cooled and the charge is drawn then the kiln may be recharged. Each time the kiln must again be reheated—a process involving both loss of time and a waste of fuel.

The intermittent kiln is usually located on the side of a hill, and is crudely constructed of stone and so situated that the top is accessible for charging the kiln and the bottom for drawing lime and supplying fuel. It has obvious disadvantages; yet in rural districts far from the railroad and with abundant and cheap fuel, this antiquated type of kiln suffices for the purpose for which it is constructed, namely, that of supplying a small and irregular demand. Old kilns of this sort can still be seen in farming regions in Maryland, in certain sections of the Piedmont, and are employed in burning such lime as the neighborhood demand requires.

Continuous Kilns.

There are three different types of continuous kilns in general use. These are (1) the vertical kiln with mixed feed, where the limestone and fuel are fed in alternate layers, and (2) the vertical kiln with separate feed, where the limestone and fuel are not brought into contact, and lastly (3), the chamber or ring kiln.

The vertical kiln built of stone with mixed feed is the type of kiln most widely used in Maryland. First a layer of coal and then a layer of limestone is fed in at the top, the fire is started at the bottom and works its way up. The process of charging is constantly kept going, the kiln being charged with fuel and limestone at regular intervals, and the calcined product drawn out below.

The construction of these mixed-feed kilns is cheaper than that of either the separate-feed or the chamber or ring-kiln, and in this respect has the advantage over both. Moreover, they are more economical of fuel, and, for the same size of kiln, they yield also a larger product, but the quality of the lime is on the whole of a lower grade than that manufactured in either one of the other types just mentioned.

In the mixed-feed kiln the commingling of the fuel and stone results in the ash of the fuel being more or less mixed with the lime. Also a part of the lime and ash in the superheated portions of the kiln often fuse and form a clinker on the outside of the burned lumps. These have to be discarded as well as a portion of the product which is dis-

colored by contact with the fuel. By the use of kilns where the fuel is not in contact with the stone the formation of a clinker is avoided and a better product for building is obtained. The clinker that is formed when the limestone and fuel are in contact might be used and sold, after grinding it to a powder, as hydraulic material. Usually though, the amount is relatively small and it is, therefore, considered better to discard it, casting it aside as a more or less unavoidable waste product: unavoidable, that is, when the continuous-mixed feed kiln is used, though the quantity of clinker may be reduced to a minimum by careful burning. Not infrequently the clinker lumps and under-burned stone are not separated from the product of the kiln and all are put through the pulverizer together, and so the clinker and under-burned stone thus become part of the finished product with which it is so intimately mixed and forms so small a proportion of the whole that it is extremely difficult, except by chemical means, to detect its presence. This under-burned and ground limestone that forms the core of the under-burned lime lumps when ground to a powder for agricultural use, when the lime is made from a very pure limestone, is about half as effective, weight for weight, as the caustic lime. It reacts more slowly, and so its beneficial results are not seen so soon.

Fuel in Burning Lime.

Theoretically, 112 pounds of coal will burn a ton of limestone, or, in other words, it requires 11 pounds of coal to calcine 200 pounds of lime. As a matter of fact, in actual practice, it requires 187 to 375 pounds of coal to burn 1 ton of limestone, even using the most modern kilns. The upper limit is even then generally exceeded, being about 475 pounds instead of 375 pounds. One of the greatest economies that can be effected in the manufacture of lime is, obviously, in the prevention of a wasteful use of fuel.

The range of cost to manufacture a ton of lime, which usually contain about 25 bushels, each bushel weighing about 80 pounds, is in Maryland from 6 to 9 cents per bushel, and the selling price varies from 8 to 17 cents, depending on the grade of lime and the market. Ten to 20 cents

per bushel, rarely less, is the usual price paid by farmers in Maryland who buy lime for use for agricultural purposes.

LIMES.

The limes produced by the calcination of limestone vary according to the composition of the original stone and the manipulation during or subsequent to its burning. Limestones of a fair degree of purity when burned yield caustic lime (CaO) which has the property, when mixed with water, of combining with carbon dioxide of the atmosphere to form calcium carbonate, thus returning to its original composition. Substances which harden through the process of returning to the chemical composition possessed prior to their burning or calcination are classed as simple cements. In this group are included caustic, magnesian, and hydrated limes.

Limestones carrying appreciable amounts of argillaceous impurities, namely, silica, alumina, and iron, when burned, undergo chemical changes by which the impurities unite with the lime to form new complex compounds. The products resulting from the formation of new compounds are classed as complex cements. In this group are included natural and Portland cements. In classification hydraulic limes, which are made from limestone containing more lime than necessary to combine with the contained impurities, may be grouped between the simple and complex cements.

The discussion of the following pages naturally divides itself into descriptions of caustic, magnesian, and hydrated limes; hydraulic limes and natural cement. The discussion of Portland cement, which involves the addition of other raw materials to the limestone before burning, is reserved for subsequent treatment.

According to the character and quantity of impurities in the burnt product, limes are classified as

1. Caustic limes.
2. Magnesian limes.
3. Hydrated limes.

Caustic Lime.

When a lime contains from 5 to 10 per cent. of impurities it is known and marketed as caustic or high calcium lime.

The reaction that takes place as the result of raising the temperature of limestone to the point of decarbonation may be expressed by the following formula in which the carbon dioxide (CO_2) of the second part of the equation passes off into the air, leaving calcium oxide or "quick lime" in the kiln.

$$CaCO_3 + \text{heat} = CaO + CO_2.$$

A considerable amount of this heat is released when water is added to caustic lime and it goes through the process of "slaking." The water combines with the lime to form hydrated calcium oxide or slaked lime, which has the formula $Ca(OH)_2$. Exposed to the atmosphere the hydrated lime gradually takes up carbon dioxide forming according to the equation $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$ calcium carbonate and water. The water evaporates while the calcium carbonate remains, cementing the surface of the now hydrated lime, and thus retards the recarbonation of the whole.

In preparing mortars a certain amount of sand, etc., is added to lower the cost and increase the volume and prevent shrinking as it dries. It has been suggested that a small portion of the sand combines with lime and forms silicates, but it is very doubtful whether this is the case. Examinations of old mortars have shown that their extra hardness is probably due almost entirely to more complete recarbonation, and only in a subsidiary way to the formation of silicates.*

If calcium silicate is formed from the combination of lime and the silica added as sand, it takes place very slowly, the per cent. of calcium silicate formed increasing with the age of the mortar, as was shown by the analyses which were made by Petzhold on mortars 100 to 300 years in age. Lime-cement mortars are being used largely at present, and by many architects and builders are preferred to any other sort, because their hardening, is not surficial, like the lime-sand mortars, but uniform

* Buchler, H. A. Lime and Cement, Mo. Geol. Survey, Vol. VI, p. 35.

throughout the mass. The lime-cement mortars are also stronger, more durable, and less likely to crack. The lime-cement mortar is obtained from mixing equal parts of cement and hydrated lime.* Lime-cement mortars are also water-proof, and hence hydrated lime is often used in cement mortars to make them water-proof. Lime-cement mortars trowel more smoothly than do cement mortars alone.

Magnesian Lime.

Limes containing more than 5 to 10 per cent. of MgO are classified as magnesian limes. The per cent. of magnesia, however, in a large proportion of the commercial magnesian limes is generally much higher than 10 per cent., ranging from 10 per cent. upwards to 41.65 per cent., the higher limit being the per cent. of magnesia present in a lime made from burning a pure dolomite. When the lime contains from 10 to 20 per cent. MgO the term dolomitic lime is more suitable and more commonly applied than the term magnesian lime.

The content of magnesium oxide in magnesian limes produces several noticeable effects which may be briefly stated. When water is poured on magnesian limes they not only slake more slowly but also give off less heat than the caustic, fat, or high-calcium limes. The magnesian limes are made in the same way as caustic limes, except that less heat is required for calcination. Also they expand less and set more rapidly than the high-calcium limes, and under certain conditions of burning have hydraulic properties. This, however, appears to be due, as in the case of the burned products derived from magnesites, to the formation of hydroxides in the place of carbonates. They also have hydraulic properties, but due to another cause when they contain sufficient impurities in the form of silica, iron, and alumina, and in this latter case the burned product is discussed and classified with the complex cements, which are considered later.

Hydrated Lime.

Hydrated lime is obtained by treating caustic lime with water which combines with the lime to form $Ca(OH)_2$. The following chemical

* Buehler, H. A. Lime and Cement, Mo. Geol. Survey, Vol. VI, p. 24.

equation expresses the reaction that takes place between caustic lime and water and shows how this new compound, hydrated lime, is formed:

$$CaO\,(\text{lime}) + H_2O\,(\text{water}) = Ca(OH)_2\,(\text{lime hydrate}).$$

If the lime is free from impurities the amount of water necessary to effect complete hydration in 32.1 per cent. of the weight of the lime. A less amount of water than the theoretical quantity, however, is required to thoroughly hydrate caustic limes because of the impurities that are always found in greater or less quantity in all commercial limes.

A very small portion of the lime manufactured in Maryland is hydrated, though there exists a very active demand for lime of this sort. The M. J. Grove Lime Company, of Frederick, and the Le Gore Lime Company, of Le Gore, also in Frederick County, the latter located on the Northern Central Railroad, and the former on the Baltimore and Ohio Railroad, are the only two operators in Maryland that systematically hydrate a portion of their product to meet this present and growing demand. Beginning April 1, 1910, hydrated lime will be placed on the market by the recently constructed plant of the Tidewater Portland Cement Company, at Union Bridge. To meet the constant inquiries made with reference to hydrated lime, its manufacture, chemical composition, physical appearance, general properties, and uses it has seemed advisable to state the following facts:

MANUFACTURE OF HYDRATED LIME.—In preparing hydrated lime on a commercial scale three stages of manufacture are necessary. These are:

(1) The lump quicklime must be ground to a fairly uniform small size.

(2) The powder or grains resulting must be thoroughly mixed with sufficient water, when the grains become a fine powder.

(3) The slaked lime must finally be sieved to separate out unhydrated lumps and cores from the fine powder.

Numberless patents have been issued to cover one or more of the points above named, but the general stages are the same in all. These will now be taken up separately and briefly discussed.

Grinding of Quicklime.—Although grinding is practiced at most hy-

drated lime plants, great variations exist in the extent to which it is carried. In a few plants the quicklime is simply crushed to about 1-inch sizes, while at others the quicklime is first crushed and then reduced to a powder, the greater portion of which will pass a 50-mesh sieve. The plan adopted in the most successful hydrating plants consists in crushing the lime by means of a pot crusher or Sturtevant Open-Door Crusher. This reduces it to pieces about ½ inch and under. It is well to note here that in burning lime which is to be hydrated, it is not necessary to employ such a high temperature as is ordinarily used. Where lime is transported in lumps, it is found necessary to partially vitrify the outside of these in order to prevent their falling to pieces in the cars. Where the lime is to be hydrated, however, this is unnecessary, and all that is required is to have all of the carbon dioxide driven off, which may be effected at a temperature of less than 1000° C.

Mixing with Water.—There are quite a number of processes and machines for hydrating lime. The only two, however, which are used to any very great extent are the Kritzer and the Clyde. The latter of these two machines has given entire satisfaction when used for hydrating magnesian limes. With high calcium limes, however, the slacking takes place very quickly, and for these the Kritzer process is now being more extensively employed.

The Clyde process hydrator is a batch machine in which a given quantity of lime, usually 1 ton, is placed, and to this is added the proper quantity of water by means of a spray. The machine itself consists of a revolving pan provided with plows, which stir up and mix the water and the lime. The water is weighed and added in a predetermined amount. When the operator judges the process to be completed, the lime is scraped from the pan through an opening in the center of the pan into a hopper below the hydrator, when it is ready for sieving.

The Kritzer process is a continuous one. The hydrator consists of a number of cylinders, one over the other, which are provided with paddles revolving around a central shaft. The lime is fed into the upper cylinder in a continuous stream and here water is sprayed upon it, the amount being regulated by valves. The moist lime is worked by the paddles and

passes from the upper cylinder to the lower ones. When it finally works its way out of the bottom cylinder, it is entirely hydrated and dry. The steam from the lower cylinders passes up through the upper ones and helps to hydrate the lime.

The amount of water to be added in each case is determined by experience. The more calcium oxide the lime contains, the more water must be added.

Sieving the Product.—After slaking, the lime is in the form of a very fine, light, fluffy powder, all of which will pass through a very fine sieve. It, usually, contains, however, cores of unslacked lime. These latter constitute the siliceous portions of the limestone, which have been partly vitrified. They are separated from the hydrate by sieving. This is usually done by means of an inclined screen, several forms of which are upon the market. In one type the sieve oscillates, in another the wire cloth is covered by small metal bands, upon which hammers fall and bounce the material through. The cores are often ground finely in a Fuller-Lehigh mill and sold for agricultural lime.

Packing the Product.—Hydrated lime is now very conveniently packed in paper bags, and automatic sacking machines have been devised which allow it to be packed very rapidly in bags which are pasted shut before the lime is placed in them, this latter being done by means of a valve in the bag. These bags present a square appearance, and not the ragged end of a hand-tied bag.

Cost of Equipment.—A plant for the hydration of magnesian limes, having a capacity of 3 tons per hour, can be equipped for about $5000. This does not include buildings, which would probably add $2000 to this. A plant of double this capacity could be built for about $7000, exclusive of buildings. The first plant would require about 30 H. P. and from four to five men, while the second plant would employ from six to eight men and require from 40 to 50 H. P.

The equipment of a plant for the hydration of high-calcium lime by the Kritzer process, having a capacity of from 4 to 5 tons per hour, would cost $12,000, to which must be added the cost of the building. From

four to five men would be required for the operation of the plant, and about 50 H. P. would be needed.

Cost of Hydration.—Manufacturers very often calculate that the cost of hydrating lime is borne by the increase in product, for instance, in hydrating a ton of lime (2000 pounds) there will be obtained from 2400 to 2600 pounds of hydrated lime.

PROPERTIES OF HYDRATED LIME.—Hydrated lime has certain properties that give it a great advantage as a marketable product over the unhydrated or caustic lime. For example:

1. It will keep indefinitely when packed in barrels or sacks or even paper bags.

2. It can be shipped by water and can be stored without danger of causing fire.

3. It does not expand when water is added and consequently can be packed and shipped in sacks.

4. Its mortar shows less danger of "popping" in the wall as sometimes occurs when incompletely hydrated caustic lime is used.

5. It may be added to cement either for the purpose of water-proofing the latter or to make a more easily troweled mortar.

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Uses of Lime.

The foregoing discussion of the limes has been classified according to their composition and method of manufacture. In the following pages

they are considered according to their uses. Broadly speaking the uses of lime may be classified into four groups:

1. Building material, as mortars or building limes.
2. Soil amendent or fertilizer or agricultural lime.
3. Chemical uses.
4. Metallurgical uses (see pp. 234-249).

BUILDING LIMES.—Both the caustic and magnesian, or dolomitic, limes are used for building purposes. The caustic limes are generally preferred because of their quicker setting properties, but locally this is not the case. The magnesian limes are sometimes preferred by reason of the fact that they possess the property of setting more slowly than the caustic limes and are "cooler working," since when water is added they slake more slowly and hence release less heat. The fact that the magnesian limes are "cooler working" sometimes results in their being used without being completely slaked, their "cooler working" suggesting to the laborer accustomed to work with caustic limes a state of complete hydration before the hydrating process or slaking is completely finished. Limes that contain considerable quantities of silica, alumina, and iron—the argillaceous limes—are, however, not viewed with favor because of their hydraulic properties, and because of their iron content which gives the lime a dark color. There is no reason though why they could not under certain circumstances be used to advantage.

AGRICULTURAL LIMES.—The term "agricultural lime" has come into use as a trade name, but lime used for agricultural and lime used for building purposes differ in no way whatever that can be distinguished chemically. The lime that is sold to the farmer and the lime that the manufacturer ships to the builder may be used indiscriminately for either purpose. The term "agricultural lime," however, is sometimes applied to building lime that has been either air or water slaked. The same term is used also in reference to the quality of the stone from which the lime is derived, and further in reference to the inferior quality of the product. Thus a lime which would not be acceptable to the builder might nevertheless be profitably employed for agricultural purposes by the farmer. But the farmer is almost as particular about the grade or quality of the lime

he uses as the builder is, and insists on a high-calcium lime and demands the same product from the kiln that the builder buys.

Lime has been used more or less extensively for agricultural purposes for a very long time. It is known to have been used on land to some extent before the beginning of the Christian era. However, its more extensive use in America dates from the first of the nineteenth century. Since then the practice of applying lime to soil has become very common and its value in improving the productiveness of the soil is well recognized. It has been shown not only to add to its productivity, but also when used in connection with other fertilizers to actually lessen the total cost of fertilization.*

At present a very large proportion of the lime manufactured is used by those engaged in agricultural pursuits. Especially is this true as to a great and increasing number of the farmers of Maryland, among the more educated and intelligent of whom liming the land is rightfully regarded as an absolute necessity.

Until within a comparatively recent period the chemical and physical effects on the soil resulting from applications of lime have been but slightly studied and very little understood. Investigations that have been carried on have shown that lime in itself is of little value except as an indirect fertilizer.

When a soil is treated with lime the latter unites with other substances in the soil and compounds are formed which have an important influence on the fertility of the land. Alumina and silica are the two principal clay substances, and lime unites with these to form double silicates. The double silicates, in which lime replaces part of the alumina, have also an affinity for and combine with ammonia, potash, and soda. The soda replaces the lime, which in turn may be replaced by potash or ammonia.

Lime also reacts with the potash feldspar fragments that may occur in the soil, releasing the potash which then combines with the double silicates of alumina, thereby becoming available as a plant food. Lime

* Md. Agric. Exp. Station, Bull. 110.

reacts with manures and organic compounds, and promotes the formation of ammonia and double silicates. If the manure is applied too abundantly a great part of the ammonia is driven off and lost, and much of the organic matter is destroyed.

Phosphoric acid, combined with iron and alumina, is potential as a plant food, but in this form is inert. When, however, these phosphates of iron and alumina come in contact with lime reactions result which make the contained phosphorus immediately available for plant consumption. Lime is further of value in neutralizing the organic acids. These acids result from the decomposition of plants of all sorts. They occur on both wet and dry soils, but are developed chiefly on the former. The presence in the soil of a large amount of these "humic" or organic acids is especially favorable for the growth of many coarse and undesirable plants. On the other hand, they seriously interfere with the growth of nitrifying ferments and hinder also the development of leguminous and a great number of other useful plants. A slight amount of acidity of the soil, however, is considered not undesirable, but to correct any excess of it lime is probably the best and most economical substance that could be used.

The chemical reactions that take place between lime and the constituents of the soil result in some very important physical changes. This is particularly noticeable in soils which are either very clayey or very sandy. The clayey soils generally show a marked tendency to remain cold and moist, to compact and to harden. The sandy soils, however, are more porous, absorbing water with a much greater avidity than clayey soils, but retaining it in the form of moisture for a much shorter period.

Lime when applied to clayey soils groups the fine particles together. The reaction that results in this condition is known as "flacculation." The soil becomes more porous and friable. Openings occur which not only permit the freer descent and absorption of water by the soil, but also augment the passage of moisture upward by capillarity. Besides this these new and enlarged openings allow an increased passage through

the soil of both heat and air, thus promoting nitrification and bringing about a more comfortable environment for the growing plants.

When lime is added to sandy soils the object is not to create better conditions for nitrification but to bring about reactions between the lime and the constituents of the soil whereby new and better physical conditions for plant life are brought about. A short distance below the surface a more or less impervious layer forms what is known as a "hard-pan." This arrests the too free passage of water downward. Lime on sandy soils has, therefore, a cementing action. The silicates that are formed hold the soil together, and consequently the porosity of the soil is diminished. Hence the soil will then absorb somewhat less water, but what it does absorb it will retain in the form of moisture for a much longer period than in the more porous state that existed before the application of lime.

The physical changes resulting from the chemical reactions between lime and the constituents of dominantly sandy soils is thus seen to be quite the reverse from that taking place between lime and the constituents of clayey soils. In sandy soils the ratio of iron and alumina to silica is very different from this same ratio in clayey soils, and hence compounds are formed in the one case that are physically very different from those of the other.

The condition of the crops more than anything else determine whether the land needs an application of lime, and numerous easy methods have been proposed for determining its necessity, but none of them are very reliable. A simple test that is probably as good as any is to wet a sample of the soil and bring in contact with a piece of blue litmus paper. If this turns red very rapidly it is an indication that the soil contains a considerable amount of acid and would be benefited by an application of lime.

The residual soils of limestone regions are often as much in need of applications of lime as the soils derived from other and more acid rocks, such as sandstones or shales. This is because in time the original lime in the soil is dissolved and leached out by descending carbonate waters,

leaving the soil cherty, siliceous, and ferruginous, and greatly diminished in productivity.

There is no little difference of opinion among farmers on the question of liming land. The great majority of them, however, have been convinced of its beneficial effects by resulting increased yields in their crops. Some of them think that the lime should be applied in large quantities and at intervals of several years, and others are of the opinion that better results are obtained by using smaller amounts and making more frequent applications. The amount used per acre, either in the case of small and frequent applications, or where the farmer applies large amounts at intervals of a period of years, vary in different sections. This is due to a small extent to the custom of the neighborhood, but more especially and frequently it is because of the differences existing between the soils of the separate sections.

Investigations that have been carried on and are still in progress at agricultural experiment stations in different parts of the United States to determine the amount of lime that should be applied per acre and the intervals at which the land should be limed, point to the fact that the best results are obtained by the application of small amounts at frequent intervals. The old idea that an acre should be treated with 100 bushels of lime at long, instead of with smaller amounts at frequent, intervals has been shown to be a mistaken one. It has been demonstrated that the crops are more benefited by applications of small amounts made annually than by large amounts applied every three or four years. Also, it is now generally recognized that a single application to poor and sandy soils should be small, and that the applications should be made annually.

As to the number of bushels of lime and frequency of application some very interesting and instructive results are presented in the Maryland Agricultural Experiment Station Bulletin No. 110 (p. 9). These results are tabulated in the table which is quoted below. It is very clearly brought out that 20 bushels of lime to the acre, applied annually, is proportionately more effective when the cost of the lime and results are considered than applications of 50 to 60 bushels.

VALUE OF GRAINS PRODUCED PER ACRE WITH DIFFERENT QUANTITIES OF LIME.
(IN DOLLARS AND CENTS.)

	Quantity of lime, bu.	Value of lime, dollars.	Value of gain of corn at 30c. bu., 1896.	Value of gain of wheat at 90c. bu., 1897.	Value of gain of hay at 50c. cwt., 1898.	Value of gain of corn, 1899. Gain at 40c. bu.	Fodder at 20c. cwt.	Total value of grains.	Relative profits from grains.
1	10	1.80	2.88	3.06	7.45	3.28	0.09	16.16	14.36
2	20	3.60	2.79	4.59	6.78	4.60	0.54	19.30	15.70
3	....none	..	..	..	..	..	..	....	....
4	30	5.40	2.85	5.49	5.97	3.12	0.72	17.97	12.57
5	40	7.20	3.24	8.37	6.55	3.80	0.45	22.41	15.21
6	....none	..	..	..	..	..	..	....	....
7	50	0.00	3.75	7.56	5.60	5.12	0.63	22.66	13.66
8	60	10.80	4.05	8.91	6.37	6.16	0.99	26.48	15.68

A number of different kinds of lime are used for agricultural purposes. These are (1) high-calcium limes, (2) magnesian limes, (3) oyster-shell lime, and (4) slaked or hydrated lime.

A high-calcium lime is made from burning a limestone analyzing from 50 to 55 per cent. calcium oxide and 40 to 55 per cent. carbonic acid, and containing small percentages of magnesia, silica, iron, and alumina. A lime derived from a stone of this character would yield 90 to 98 per cent. of calcium oxide, and would weigh directly after withdrawal from the kiln 90 to 95 pounds to the bushel, and will slake about 3 bushels for 1 in volume.

Magnesian limes used in agriculture run from 5 to 20 per cent. in magnesia and 70 to 85 per cent. in calcium oxide. They weigh less than the high-calcium lime. A bushel of magnesian lime weighs about 70 pounds, and slakes about 2 bushels for 1 in volume. Oyster-shell lime weighs about 60 pounds to the bushel and contains from 85 to 95 per cent. of CaO.

CHEMICAL USES OF LIME.—Lime is used in chemical processes either unslaked as it comes from the kilns, or slaked to the hydrated form when it is used either dry or mechanically suspended in water as "milk of lime." It is also used in solution as lime water to a small extent. In all cases, except the manufacture of caustic alkalies, a magnesium-pure calcium-rich lime is preferred.

Unslaked Lime.—Unslaked lime is used for the manufacture of calcium carbide and cyan amide and as a cleansing or refining agent in the manufacture of glue and sugar, in the tanning of hides, and in the dyeing of textile fabrics. *Calcium carbide* is obtained by fusing a mixture of unslaked lime and carbon, in the form of coke or charcoal, in an electric furnace. The process demands considerable electrical current compared with the value of the product, and is usually limited to localities where abundant waterpower warrants the erection of large hydro-electrical plants. Calcium carbide is used in the making of acetylene gas and in the preparation of cyan amide. *Cyan amide* or "lime nitrogen" is manufactured by the use of either calcium carbide or, what in the end amounts to the same thing, a heated mixture of lime and coke, over which is passed nitrogen gas obtained from liquid air. All the steps in the process by which this substance is made have been patented since cyan amide bids fair to become one of the most important fertilizers in the market. It can also be used in the manufacture of ammonia.

Lime unslaked, or hydrated in the form of "milk of lime," has the power of dissolving certain organic tissues, thereby disintegrating particles of flesh, and of absorbing fatty substances and oils with saponification. This renders the material valuable in the preparation of glue and the tanning of hides. *Glue* is manufactured from raw materials, chiefly slaughter-house and fishery refuse, which has been treated with lime for a period of six weeks to several months to remove the oils, flesh and blood, and to soften the more resistent tissues and marrow. Lime is also used in the early stages of the *tanning* processes where the hides are "limed" to saponify the fats and break down the particles of flesh adhering to the skin. The lime also attacks the epidermis of the hides and is very serviceable in loosening the hair and softening or "plumping" the leather. Lime is also used in the manufacture of *sugar* when the so-called second molasses, containing about 40 per cent. sugar, is treated with quick-lime to produce an insoluble tricalcium sucrate which may be filtered off and subsequently decomposed with carbon dioxide yielding calcium carbonate and a solution of sugar. This process is particularly used in beet-sugar refining.

Slaked Lime.—Slaked lime is used dry in the preparation of bleaching powder, or chloride of lime, which is largely demanded in the industries or as a disinfectant. The slaked lime is placed in leaden vats and treated with chlorine gas. The use of slaked lime suspended in water in the form of minute particles—milk of lime—is perhaps the most commonly employed form in chemical industries. In this form it is used in the manufacture of ammonia, caustic soda and potash, the purification of water, the refinement of sugar, and also in tanning and other industries. *Ammonia* is produced as a by-product in the manufacture of coal gas from coke furnaces and of water gas, obtained by the passing of steam over heated anthracite with subsequent enrichment by the addition of oil. The gases thus obtained are washed to remove ammonia and tarry matters. The ammoniacal liquors are distilled to obtain the free ammonia and then treated with lime to break down the ammonium compounds, such as ammonium sulphate, thereby releasing the additional ammonia. Lime is also used in gas manufacture to absorb any sulphur or excess of carbon dioxide in illuminating gas. The *caustic alkalies,* soda and potash, are made by the treatment of sodium and potassium carbonate with milk of lime, caustic soda and caustic potash being formed with a precipitation of calcium carbonate. This is one of the few processes in which lime is used where it is not necessary to employ a lime low in magnesia. It even becomes advisable at times to use hydrate of magnesia rather than hydrate of lime, or a mixture of the two, since it is particularly serviceable in the manufacture of caustic potash. In the *purification of water* calcium hydroxide, or the hydrate of lime, is used to free the water from the soluble calcium bicarbonates. According to the action which takes place all of the lime is precipitated in the form of calcium carbonate, thereby softening the water. Milk of lime is also used to defecate the *sugar* extract in the early steps of the sugar refining, the action resulting in the neutralization of the organic acids and the coagulation of the albumen and mucus.

Hydrate of lime is also used in the manufacture of the finer qualities of glass in place of the pure limestones in order to do away with any possible ribboning of the glass through the movement of the escaping

carbon dioxide through the molten glass. Care must be used to avoid possible variations in the composition of the calcined product, due to partial hydration or contamination from the ash from the kilns.

HYDRAULIC LIMES.

Limestones containing appreciable amounts of impurities sufficient to give the calcined product hydraulic properties but insufficient to take up all the lime present are classed as hydraulic limes. They form an intermediate between simple limes and complex cements. According to their content of clayey matter they may be classified as *hydraulic* limes or as *eminently hydraulic* limes, the latter including Grappiers cements. Both are feebly hydraulic as compared with good natural cement or with Portland cement. The materials adapted for the manufacture of the poorly hydraulic limes contain small amounts of argillaceous matter and may be either calcareous or magnesian, the magnesia present acting almost interchangeably with the lime. Usually they contain from 45 to 48 per cent. of lime and magnesia, the content of the latter varying from a trace to three-quarters of the per cent. of the former, and 4 to 7 per cent. of iron and alumina, with 5 to 8 per cent. of silica. On the other hand, the eminently hydraulic limes are made from limestones that carry 39 to 45 per cent. of lime, 13 to 17 per cent. silica with alumina, and iron rarely exceeding 3 per cent. The form in which the impurities, especially silica, occur is also important, the stone improving with the degree of dissemination of the free silica and the increase in silicates. When the silica is combined less heat is required for "burning," and the fuel cost is accordingly lessened.

Both the hydraulic limes and the eminently hydraulic limes are burned in kilns very similar in type to the continuous lime kilns. The temperatures maintained in the kilns necessary to produce decarbonation is, however, higher than is required to drive off the carbon dioxide (CO_2) of non-argillaceous limestones. This is due to the presence in these limestones of their characteristic argillaceous content, which unites with a portion of the lime to form a clinker. The excess of lime which remains

uncombined is both necessary and desirable, for, by the addition of water, it slakes and disintegrates the siliceous clinker.

Compared with Portland cement or natural cement, both kinds of hydraulic limes are very feebly hydraulic. They are not manufactured in Maryland or indeed, so far as the writers are aware, in any part of America, though the materials for their manufacture certainly are not lacking. That, however, there is a demand for their use in this country is evidenced by the fact that a considerable quantity of both hydraulic lime and Grappier cements is annually imported from abroad, where the industry is one of no little importance. La Farge, the well-known non-staining cement, is a Grappier cement, and this is largely imported into America. It is probable, however, that it will be gradually replaced by the white Portland cements now made in this country. The composition of the eminently hydraulic lime, or Grappier cement rocks, vary in their content of lime from about 45 to 47.50 per cent. The silica ranges from 13 to 17 per cent., and the sum of the alumina and iron rarely exceeds 3 per cent. On the other hand, the feebly hydraulic lime rocks from which the product selenitic lime is made show a lower content of argillaceous materials. The silica runs 5 to 7.50 per cent., and the iron and alumina from 4 to 7 per cent., with a lime cement of 40 to 48 per cent. The composition of the burnt products varies, of course, with the kind of stone used, and the analyses available show that the feebly hydraulic limes contain from 65 to 80 per cent. lime, together with some magnesia, and from 7.5 to 16 per cent. silica with the iron and alumina together varying from 5+ to 12+ per cent.

Hydraulic and Cementation Index.—The combination of lime with the argillaceous impurities during burning produces a series of chemical compounds in the clinker which when ground give to the powder the property of hydraulicity or the power to set upon the addition of water. The degree to which this hydraulic power is developed depends upon the closeness of approach to the complete transformation of the burnt mass into certain definite relations with lime as the base. Formerly it was thought possible to work out an accurate classification of cements

possessing hydraulicity based on the ratio of the silica and alumina with lime according to the following formula:

$$\text{Hydraulic index} = \frac{\text{per cent. silica} + \text{per cent. alumina}}{\text{per cent. lime}}.$$

The values obtained by the use of this formula permit the tabulation of limes and cements by their hydraulic indices as follows:

HYDRAULIC INDEX.	PRODUCT.
Less than 0.10*	Common lime.
0.10-0.20	Feebly hydraulic limes.
0.20-0.40	Eminently hydraulic limes.
0.40-0.60	Portland cement (if burned at high temp.).
0.60-1.50	Natural cements.
1.50-3.00	Weak natural cements.
3.00	Puzzolans.

The term hydraulic index is merely empirical, and a great many attempts have been made to devise formulas which would express in scientific terms the hydraulic value of limes and cements. This has been unsuccessful for a number of reasons; chief of which is the fact that nearly all of these materials owe their properties not only to chemical composition but also to physical state and process of manufacture. Nearly all formulas have supposed that cements and hydraulic limes owe their hydraulic properties to definite chemical compounds. The most recent investigations which have been made upon this class of materials tend to prove that they are not definite compounds but are what are known to physical chemists as solid solutions, and are similar in character to blast furnace slags, steel, and alloys. It would seem better, therefore, to classify these compounds according to their physical properties and method of manufacture, rather than according to their chemical characteristics. Such a classification would be the following:

(1) *Common Lime.*—Limes made by burning relatively pure limestones which, when mixed with water, slake and show no hydraulic properties.

(2) *Hydraulic Limes.*—Limes made by burning impure limestones at a low temperature which slake with water, but which show hydraulic properties.

* Eckel, E. C. Cements, Limes, and Plasters, p. 169.

(3) *Natural Cements.*—Cements which are made by burning impure limestones at a low temperature (insufficient to vitrify) which do not slake with water, but require to be ground in order to convert them into a hydraulic cement.

(4) *Portland Cement.*—Hydraulic cements which are made by heating to incipient vitrification a mixture of argillaceous and calcareous substances, which product does not slake with water, but upon grinding forms an energetic hydraulic cement.

(5) *Puzzolan Cement.*—Cements which are formed by incorporating slaked lime with a finely ground slag or volcanic ash.

DIAGRAM OF LIMES AND CEMENTS.

Raw materials.	Chemical treatment.	Mechanical treatment.	Hydraulic or not.	Classification.
Made from relatively pure limestones.	Burned at low temperatures. 600°—1200° C.	Slake on addition of water to burned product.	Not hydraulic.	1. Common limes.
Made from argillaceous or impure limestones.				2. Hydraulic limes.
				3. Natural Roman or Rosendale cement.
Made from an intimate mixture of argillaceous and calcareous substances in proper proportions.	Burned at high temperatures, 2500°—3000° C.	Do not slake on addition of water but must be ground finely for use.	Hydraulic.	4. Portland cement.
Made from mixtures of slaked lime and blast furnace slag or volcanic ash.	Not burned.			5. Slag or puzzolan cements.

NATURAL CEMENTS.

Grouped under the name of natural cements are those products resulting from burning and subsequent grinding of the natural mixtures of calcium carbonate and clay found in the form of clayey or argillaceous limestone. Such limestones may be recognized in the field by the characteristic clayey odor that is given forth when they are breathed upon,

and on analysis in the laboratory by the fact that they carry from 13 to 35 per cent. of clayey material, of which 10 to 22 per cent. is silica. The alumina and iron oxide together may vary from 4 to 16 per cent. It is the presence of these argillaceous materials in the limestone, which may or may not also contain magnesium carbonate, that give the resulting product its hydraulic properties, but it was long thought that the presence of magnesia was equally essential. Experiment has shown, however, that this is not the case. Magnesia, when present, acts almost interchangeably with the lime, and in replacing the latter it is supposed neither to add to nor detract from the hydraulicity of the finished product.

RAW MATERIALS FOR NATURAL CEMENT.

These argillaceous limestones, from which natural cement is made, are widely distributed both geologically and geographically. During the canal-building period of the country's history they were much sought after. (Certain of the plants in Maryland were started about this time.) They have been found and manufactured into cement of more or less value in nearly every State in the Union. At present, however, the important natural cement-producing districts are comparatively few. The plants that have flourished have been those that, besides possessing abundant raw material of steady composition, located so as to be easily and economically mined or quarried, also have been favorably situated for cheap transportation, and have enjoyed the advantages of a good local market, and further have been able to obtain fuel at reasonable rates.

Of the 65 plants in the United States, reported in operation by the U. S. Geological Survey in 1903, three were located in Maryland.

An examination of the analyses of the raw materials and of the collection of products included under the name of natural cements brings out the fact (as illustrated by the analyses given further on) that the chemical composition of both the natural cement rock and the finished products varies within very wide limits. It is not surprising, therefore, that the finished products show corresponding differences both in the strength, the cementation index, and also the rate of set.

In the table of natural cement rocks below, there is presented a series of more or less typical analyses of cement rocks from seven of the more important districts in the United States.

ANALYSES OF NATURAL CEMENT ROCK.*

State	District	Silica (SiO_2).	Alumina (Al_2O_3).	Iron oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Alkalies (K_2O, Na_2O).	Sulphur trioxide (SO_3).	Carbon dioxide (CO_2).	Water.	Cementation index.
Illinois	Utica	12.22	9.89	3.90	24.40	10.43	n. d.	n. d.	33.48		1.21
Ind.-Ky.	Louisville	9.69	2.77	1.95	29.09	15.69	n. d.	n. d.	40.14	....	0.618
Kansas	Fort Scott	21.30	3.70	3.10	35.00	3.50	....	....	33.00	....	1.68
Maryland	Hancock	19.81	7.35	2.41	35.76	2.18	n. d.	n. d.	31.74		1.68
Minnesota	Mankato	16.00	5.85	2.73	22.40	14.99	0.76	n. d.	34.11	....	1.22
New York	Rosendale	18.52	6.34	2.63	25.31	12.13	n. d.	0.90	33.31	....	1.43
Virginia	Balcony Falls	17.30	6.18	1.62	29.54	13.05	....	....	34.17	....	1.18
Average		17.24	6.05	2.16	28.06	11.51	0.76	0.90	34.98	....	1.29

* Eckel, E. C. Cement, Limes, and Plasters, Chapter xvii.

It will be seen in looking over these analyses that when an analysis from one district as compared with that of another there is, in certain instances, a considerable variation in chemical composition, and the differences in the cementation indices will also be observed. The following analysis gives the average chemical composition of the natural cement rocks from these seven different districts just referred to:

AVERAGE OF ANALYSES OF NATURAL CEMENT ROCK.

SiO_2	17.24
Al_2O_3	6.05
Fe_2O_3	2.16
CaO	28.06
MgO	11.92
$K_2O + Na_2O$	0.76
SO_3	0.90
CO_2	34.98
Cementation Index	1.29

MANUFACTURE OF NATURAL CEMENTS.

In order to convert the natural cement rocks into natural cement these rocks are burned to a temperature not less than 1000° C., and for the best results between 1000° and 1100° C. In the burning process the

clayey materials are first attacked by the lime which begins to form by the decarbonation of the limestone at temperatures as low as 610° to 650° C. At 1000° C. practically all but a trace of CO_2 is driven off. After the clayey materials combine with lime near the highest and final heat of the kiln the remaining lime combines next with the more stable silicates, and lastly with free silica. The burning is done in kilns very similar to those used in burning lime. After burning, before the material is ready for sale, it has to be ground to a fine powder. The burned material is ground and packed either into sacks or bags, and is then ready for the market. The raw materials and these finished products vary greatly, in chemical composition, but their composition may be expressed only approximately, considering the variation in composition of different brands, by the typical formula 1.60 RO, 0.23 Al_2O_3, SiO_2.

COMPOSITION OF NATURAL CEMENTS.

The difference in composition of natural cement rocks which has already been given is most marked and, as might be expected, there are very noticeable corresponding differences in the composition of finished products. These differences of composition are sometimes further accentuated by the conditions of burning, which not only modify the chemical composition but also produce greater or less differences in the physical properties.

ANALYSES OF NATURAL CEMENTS.*

State.	District.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Alkalies (K_2O, Na_2O).	Sulphur trioxide (SO_3).	Carbon dioxide (CO_2).	Water.
Illinois	Utica	19.89	11.61	1.35	29.51	20.33	5.96	n. d.	n. d.	....
Ind.-Ky.	Louisville	23.18	7.87	1.73	43.79	10.43	2.22	n. d.	9.28	
Kansas	Fort Scott	23.82	6.99	5.97	53.96	7.76	....	....	2.00	
Maryland	Hancock	29.74	8.34	4.14	45.66	2.86	....	....	3.13	
Minnesota	Mankato	28.43	6.71	1.94	36.31	23.89	1.80	n. d.	0.92	
New York	Rosendale	27.75	5.50	4.23	35.61	21.18	2.00	0.50	4.05	n. d.
New York	Akron-Buffalo	17.14	7.61	2.00	36.83	25.09	3.64	n. d.	n. d.	n. d.
Average		24.20	7.80	3.06	40.24	15.94				

The Maryland Natural Cements have a very high index, exceeding that of the Rosendale Cements. The Maryland Cements, moreover, are low in MgO, while the Rosendale Cements are high.

* Eckel, E. C. Cements, Limes, and Plasters, Chapter xix.

During the process of burning a unit of natural cement rock the carbon dioxide is or ought to be almost entirely driven off, and, accordingly, the percentage of argillaceous materials and calcium oxide in the cement is correspondingly increased. In the table of analyses of natural cements, this fact will be noticed as well as their differences in composition.

After natural cement rock has been sufficiently burned, the clinker is ground to a fine powder. The finer the clinker is ground the better are the results obtained. It should be ground so that 90 per cent. will pass through a 100-mesh screen. The grinding is done by suitable machinery designed for the purpose.

The cost of manufacturing natural cement varies in different localities, ranging from 20 to 50 cents per barrel, depending on local conditions.

RELATIONS OF NATURAL AND PORTLAND CEMENTS.

Natural cements are closely related both to hydraulic limes and to Portland cement. They differ, however, with respect to the hydraulic limes in that the burned mass does not slake when water is poured upon it. This is due to the fact that, in the case of natural cements, the carbon dioxide of the limestone is almost entirely driven off, and all, or nearly all of the resulting calcium oxide combines with the argillaceous materials. On the other hand, the chief points of difference between natural and Portland cements have been briefly and well summarized by Eckel * as follows:

1. Natural cements are not made by burning carefully prepared and finely ground artificial mixtures, but by burning masses of material rich in argillaceous impurities at temperatures, approximately, of 900° to 1000° C.

2. Natural cements, after burning and grinding, are usually yellow to brown in color and light in weight, their specific gravity being about 2.7 to 3.10, while Portland cement is commonly blue to gray in color and heavier, its specific gravity ranging from 3.0 to 3.2.

* Eckel, E. C. Cements, Limes, and Plasters, p. 195.

3. Natural cements are always burned at a lower temperature than Portland, and commonly at a *much* lower temperature, the mass of rock in the kiln rarely being heated enough to even approach the fusing or clinkering point.

4. In use natural cements set more rapidly than Portland cement, but do not attain such a high ultimate strength.

5. In composition, while Portland cement is a definite product whose percentages of lime, silica, alumina, and iron oxide vary only between narrow limits, various brands of natural cements will show very great differences in composition, while even the same brand, analyzed at different times, will show considerable differences in composition due to variations in the natural limestones used.

PORTLAND CEMENT.

Portland cement, like hydraulic lime and natural cement, is characterized by the property of setting under water which is due to certain chemical compounds produced by the burning of limestone mingled with certain impurities. Unlike the natural cements and hydraulic limes which are formed by the burning of varying natural mixtures of calcareous and argillaceous matter, Portland cement is the product of treating a carefully prepared artificial mixture of almost fixed composition. To assure the desired uniformity of composition necessitates more complicated processes of manufacture which will be described in detail in the following pages. In order that the bearing of the extended discussion of details may be clear to the average reader the general process of manufacture of Portland cement is briefly sketched.

The original mixture prepared for burning consists of calcareous and argillaceous matter in the general proportion of 2 of the former to 1 of the latter.

To assure the uniform mixture of the two substances and their chemical union during burning the raw materials are finely ground.

After these have been pulverized and mixed in proper proportions they are burned in rotary kilns at a temperature of 1600° to 1700° C., or

3000° F., to ensure incipient fusion. During the burning process the silica, alumina, and iron, which together form a large percentage of the argillaceous material with which the limestone is mixed, combine with lime and form the compounds that give this cement its peculiar hydraulic properties.

The clinker that is formed at the high temperature of the kiln is then passed through grinding and pulverizing mills and thus reduced to an impalpable buff-colored powder that has, when first ground, an average specific gravity of about 3.20. As this powder is exposed to the air the specific gravity becomes less and may fall as low as 3.00 after long storage. It is heavier than the powder of the natural cements, and on the addition of water sets more slowly but has both an early and an ultimate tensile strength that is much greater than any of the natural or rock cements.

COMPOSITION OF PORTLAND CEMENTS.*

It was the generally accepted belief for about 20 years that the essential element in Portland cement was tri-calcium silicate ($3CaO \cdot SiO_2$), and that it was to this compound that the setting and hardening properties of Portland cement were chiefly due. As to the state of the combination of alumina, however, there had been some doubt. Le Chatelier contended that the alumina was present as tri-calcium aluminate ($3CaO \cdot Al_2O_3$), while Newberry held that the alumina was present as dicalcium aluminate ($2CaO \cdot Al_2O_3$). Some 10 years ago Törnebohm, a Swedish petrographer, identified in cement, by the use of the microscope, four distinct constituents, which he called, respectively, *alit, belit, felit,* and *celit.* Alit, he stated, was the essential constituent of Portland cement and good Portland cement clinker consisted almost entirely of it. Richardson, in 1904, stated that alit was a solid solution of tri-calcium silicate in tri-calcium aluminate. In 1906, Day and Shephard stated that they had found by microscopic tests that no such compound as tri-calcium silicate existed, and that what Newberry, Le Chatelier, and

* Cf. Meade, R. K. Chemical Engineer, 1909, Vol. X, pp. 183-192.

Richardson had supposed to be this compound, was nothing more than a solution of lime in calcium ortho-silicate or dicalcium silicate ($2CaO \cdot SiO_2$). Their statements were so amply backed by proof that it is now generally agreed that Portland cement is probably nothing more than a solid solution of lime in a magma of ortho-silicates and ortho-aluminates of lime. It is, therefore, as impossible to assign to Portland cement any definite chemical symbol as it is to assign one to steel, which is a solid solution of carbon, etc., in iron or to alloys, which are also solid solutions. At the same time the composition of Portland cement has a great bearing upon its physical properties, just as does the composition of an alloy upon its physical properties. The accompanying table shows the analyses of Portland cements made from various materials and from various parts of the United States.

ANALYSES OF AMERICAN PORTLAND CEMENT.†

(Made by R. K. Meade, except those marked *.)

Made from.	Where made.	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	Loss
Cementrock and limestone.	Nazareth, Pa.......	19.92	2.28	7.52	62.48	3.19	0.52	0.66	1.51	1.46
	Nazareth, Pa........	21.14	2.30	6.94	63.24	3.26	0.36	0.51	1.12	1.24
	Bath, Pa.............	19.64	2.80	7.52	62.31	3.04	n. d.		1.60	1.48
	Alpha, N.J.........	21.82	2.51	8.03	62.19	2.71	n. d.		1.02	1.05
	Northampton, Pa...	21.94	2.37	6.87	60.25	2.78	0.61	0.87	1.38	3.55
	Coplay, Pa...........	22.26	2.10	5.86	63.32	3.81	n. d.		0.89	1.24
	Omrod, Pa...........	22.20	2.27	6.69	62.61	3.00	0.32	0.61	1.32	1.56
	Martin's Creek, Pa..	20.32	2.50	7.12	62.94	3.38	n. d.		1.45	1.25
	Reading, Pa.........	24.16	1.45	5.10	62.95	3.12	0.21	0.50	1.35	1.40
Limestone and clay or shale.	Bay City, Mich......	20.74	2.85	7.17	62.64	1.97	0.48	0.12	1.42	2.58
	Wellston, O..........	21.84	5.05	6.77	62.66	0.80	n. d.		1.24	....
	Chanute, Kan........	20.72	3.72	7.06	62.76	1.78	0.41	0.23	1.12	1.40
	Ada, Okla............	22.28	3.20	6.36	59.66	3.11	0.80	0.25	1.40	2.82
	*Stroh, Ind...........	21.78	2.65	7.31	62.85	2.88	0.47		1.78	0.78
	*Glens Falls, N. Y....	21.50	10.50		63.50	1.80	0.40		1.50	n. d.
	Alsen, N. Y.........	23.94	3.20	5.62	62.32	1.77	n. d.		0.90	1.68
	Fordwick, Va........	21.31	2.81	6.54	63.01	2.71	n. d.		1.42	2.01
	Davenport, Cal......	25.38	1.20	3.84	62.96	1.20	n. d.		0.85	4.58
	Cement, Cal.........	22.84	3.30	7.00	60.72	1.30	n. d.		1.05	2.54
	*Baker, Wash........	24.63	8.56		62.88	1.60	n. d.		1.33	n. d.
	St. Louis, Mo.......	23.12	2.49	6.18	63.47	0.88	n. d.		1.34	1.81
	Demopolis, Ala.....	19.36	4.10	9.18	63.20	1.16	n. d.		1.18	1.12
Marl and clay.	*Portland, Colo......	21.88	2.85	7.14	64.94	Tr.	1.18		0.78	1.06
	*Middlebranch, O....	21.24	4.14	7.85	63.22	0.28	0.68		1.11	1.32
	*Coldwater, Mich....	21.22	3.83	7.51	63.75	0.82	n. d.		1.58	1.02
	Sandusky, O.........	21.93	2.35	5.99	62.92	1.10	0.63	0.27	1.55	2.92
	*Bronson, Mich......	22.90	3.60	6.80	63.90	0.70	1.10		0.40	0.60
	*Harper, O.	21.30	2.00	6.95	62.50	1.20	n. d.		0.98	4.62
	*Warners, N. Y.......	22.04	3.41	6.45	60.92	3.53	n. d.		1.25	......
Limestone and blast furnace slag.	Chicago, Ill.........	22.41	2.51	8.12	62.01	1.68	n. d.		1.40	1.02
		23.06	2.88	8.16	62.10	1.88	0.36	0.58	1.57	......

† R. K. Meade, 7th Int. Congr. of App. Chem.; see Chem. Eng., X, 185.

The composition * of Portland cement of good quality is usually within the following limits:

COMPOSITION OF PORTLAND CEMENT.

	Limits.	Average.
Silica (SiO_2)	20-24%	22.0%
Alumina (Al_2O_3)	5- 9	7.5
Iron oxide (Fe_2O_3)	2- 4	2.5
Lime (CaO)	60-63.5	62.0
Magnesia (MgO)	1- 4	2.5
Sulphur trioxide	1- 1.75	1.5

A number of theories have also been proposed as to just what takes place when cement sets. The older theories held that when water was added to the cement decomposition set in and new complex compounds of lime, silica and alumina were formed. Still another theory supposed that the cementing action was due to a network of fine needle-like crystals of calcium hydrate.

With the application of physical chemistry to the solution of problems of this character, a newer theory has been recently put forward, which supposes that when water is added to the clinker, gelatinous or colloidal silica is formed, and that this acts as a glue or jelly to bind the material together. Just at the present time the chemistry of cements is in a rather upset condition, due to the fact that we are changing from the older supposition that cement was a definite compound to the newer one that it is a solid solution, and this has effected all of our theories as to what takes place when cement hardens.

Practical experience has shown that the essential elements in cement are lime, silica, and alumina. Iron is present to more or less extent in nearly all clays and shales, and hence is always present in cement. Its presence may be looked upon, however, not simply as an impurity. It has a definite advantage; namely, it assists in burning. The white Portland cements have all proved hard to burn, and the more iron which a cement contains the easier it will burn.

* R. K. Meade. 7th Congress of Applied Chemistry; see Chemical Engineer, X, 184.

In preparing the raw materials for burning in the kiln, the best results can only be obtained when the four elements, lime, silica, alumina, and iron are mixed in the proper proportions; not only that, but the mixture should be a very intimate one, which can only be brought about by very fine grinding of the materials. The range of composition which is allowable in any given brand of cement is nowhere as large as that given in the above tables. Usually the limits for lime are not greater than 1 per cent. either way from a fixed standard, and very often they are not more than one-half of this. The composition of a given cement nearly always depends upon the index of activity, the percentage of iron and the degree of grinding which the raw materials are given.

The chemical constituents of Portland cement may be divided into two classes, the essential and the accessory. The essential constituents have already been mentioned as being lime, silica, alumina (and iron). The accessory constituents would include such compounds as magnesia, sulphuric acid, the alkalies, water, and carbonic acid, etc., which occur in the cement as unavoidable, accidental ingredients, or else as intentionally added impurities.

Essential Constituents of Portland Cements.

Lime is the most important of the essential constituents in the sense that its ratio in Portland cement to the other three essential elements is about as 2 to 1. In proportioning the mix care should be observed, therefore, to have the amount present neither too large nor too small. If the lime is in excess, the cement will be unsound—that is concrete formed from it will in time swell, crack, and possibly fall to pieces. If, on the other hand, the lime is deficient in quantity the cement will be low in tensile strength, of poor color, and often will set too quickly to allow the masons to place it in the forms. When the mixture is imperfect or the burning insufficient, the combination of the lime with the silica, alumina, etc., is incomplete, and a poor grade of cement is the result. In a Portland cement of normal composition the proportion

of lime falls within the limits, according to Chatelier,* determined by the following formulæ:

1. Upper limit of lime. $\frac{CaO+MgO}{SiO_2+Al_2O_3} \geqq 3.$

2. Lower limit of lime. $\frac{CaO+MgO}{SiO_2-(Al_2O_3+Fe_2O_3)} \geqq 3.$

On the whole, the greater the amount of lime that is present in cement, if it is all combined without leaving free lime, the greater will be its strength. New plants usually take advantage of this fact, and in placing their product on the market make the lime content high and burn the mixture at unusually high temperatures to obtain complete combination. As a result there is a considerable increase in the cost of manufacture, but the resulting cement is given high-testing qualities that obviously are most helpful in establishing a new brand.

The amount of *silica* in a Portland cement varies from 19 to 25 per cent. A cement with a high silica content approaching the upper limit mentioned above would imply a cement low both in alumina and iron; and conversely a cement low in silica is also generally correspondingly high in its content of alumina, and may be also high in iron. Furthermore, the high silica cements are harder to clinker than the low silica cements. They harden slowly and sometimes have trouble in meeting the short-time strength specifications, but they usually give high ultimate tensile strength. In order to avoid making a cement that will set too quickly the raw materials should be proportioned so that the silica in the resulting cement will amount to at least 2.5 times the alumina.

The amount of *alumina* permissible in a Portland cement has been given as lying between 5 and 9 per cent. Its effect upon the set of the cement is just opposite to that of silica. A cement containing from 8 to 9 per cent. of alumina is apt to set rapidly.

The tendency of high aluminous cements to set rapidly can be corrected to some extent by having the cement of low hydraulic index; that is, a high lime cement. High alumina cements are quick hardeners,

* Le Chatelier, Constitution of Hydraulic Mortars, p. 87.

and consequently cements containing from $7\frac{1}{2}$ per cent. to 10 per cent. alumina show high seven-day tests. Cements should contain at least 2.5 as much silica as alumina. This ratio between silica and alumina Meade * calls the *index of activity*. This index should lie between 2.5 and 5. Cements with an index of activity of less than 2.5 are apt to be quick-setting or else to become quick-setting on exposure to air. In order to offset this tendency to set quickly on the part of high alumina cements, it is necessary to make them relatively higher limed than those containing moderate percentages of alumina. The high lime content gives slow-setting properties which offset the quick-setting ones, due to high alumina. Cements high in alumina are hard to burn properly, owing to the fusibility of the calcium aluminate. This causes balling up and sticking together of the clinker in the hot zone of the kiln, preventing uniform burning.

Cements with an index of activity of more than five are usually very hard to burn. They are slow-setting and also slow hardeners. Their early strength is often low, but ultimately they obtain as great strength as other cements. There are a number of high silica cements on the American market which have great difficulty in meeting standard specifications as to seven-day strength.

The amount of *ferric oxide* in Portland cements is comparatively low, though it is an important ingredient. It seldom exceeds 5 per cent., and is usually below this, being generally between 2 and 4.5 per cent. It aids greatly in lowering the temperature at which the clinker is formed, and is also said to give, in replacing and lowering the amount of alumina, the cement the property of resisting the magnesium sulphate ($Mg\ SO_4$) of sea-water.

Cement made from materials containing alumina and no iron is perfectly white. It requires a higher temperature to burn, but when properly *clinkered* possesses all the setting and hardening properties of Portland cement. White Portland cements are now made at York, Pa.,

* R. K. Meade. 7th Congress of App. Chem.; see Chem. Eng., X, 187.

Canaan, Mass., and Kimmel, Ind. Below are analyses and tests of some of this white Portland cement:

ANALYSES OF SANDUSKY WHITE CEMENT, YORK, PA.

	Per cent.
Silica (SiO_2)	23.56
Alumina (Al_2O_3)	5.66
Iron Oxide (Fe_2O_3)	0.32
Lime (CaO)	64.12
Magnesia (MgO)	1.54
Sulphur Trioxide (SO_3)	1.50
Loss on ignition	2.92
Total	99.62

PHYSICAL PROPERTIES.

Fineness through a No. 100 test sieve = *94.7* per cent.
Fineness through a No. 200 test sieve = *76.9* per cent.
Boiling test, 5 hours = *Good.*
Initial Set = *3* hours and *45* min.
Final Set = *6* hours and *30* min.
Tensile strength 1 day neat = *383* lbs.
Tensile strength 7 days neat = *627* lbs.
Tensile strength 7 days sand = *213* lbs.
Tensile strength 28 days neat = *755* lbs.
Tensile strength 28 days sand = *246* lbs.

Iron does not make cement quick-setting and may be made to replace alumina to advantage in many cases. Portland cement in which iron replaces alumina is claimed to resist sea-water much better than ordinary cements.

Cements have been made almost entirely free of alumina and containing only lime, silica,* and iron oxide, together with the ordinary accessory impurities. These non-aluminous cements have proven in every way satisfactory when submitted to the most rigid tests. Ferric oxide has thus been shown to be able to replace the alumina entirely, though giving the cement a grayish color, but in no way diminishing its tensile strength or its hydraulicity.

A cement, called "Erz Cement," made from a siliceous limestone and iron ore is manufactured by the Krupp Steel Company, at Hemmoor,

* Meade, R. K. Portland Cement, p. 28.

Germany, and is intended for marine construction. It has about the following analysis:

Silica (SiO_2)	20.5
Alumina (Al_2O_3)	1.5
Iron Oxide (Fe_2O_3)	11.0
Lime (CaO)	63.5
Magnesia (MgO)	1.5
Sulphur Trioxide (SO_3)	1.0
Total	99.0

Accessory Constituents of Portland Cements.

Magnesia is considered the principal impurity in Portland cements. The standard specifications state that a Portland cement should not contain more than 4 per cent. of magnesia. As much as 5 per cent., however, is not thought by many of the authorities to be harmful. But all the manufacturers, nevertheless, are very careful to have the percentage of magnesia as low as possible in order to be well within the limits of the standard specifications.

Formerly it was thought that if a cement contained over 2 per cent. of MgO it was too high in magnesia, but now 4 to 5 per cent. is the allowable maximum in American Portlands and about 3 per cent. is the maximum according to foreign practice. Campbell and White, however, have shown that good Portland cements can be made, if the raw materials are carefully selected, proportioned, and burned, with a content of 10 per cent. magnesia. On the other hand, the investigation of R. Dykerhoff, which was presented in 1895 to the German Association of Cement Manufacturers, shows that more than 4 per cent. of magnesia in the cement decreases its strength and over 8 per cent. causes it to crack.

The amount of the *potash* and *soda* present in Portland cement varies from 0 to a little over 2.5 per cent., but rarely exceeds .75 per cent. in American cements. The cements with the higher limit of the alkalies are usually made from alkali waste. The per cent. of alkalies present in the raw materials is reduced at least one-half by the heat of the kiln.*

* Meade, R. K. Portland Cement, p. 124.

A larger amount of the potash is lost and goes off with the kiln gases than soda, since the former is the more volatile. They both act as fluxes * and promote the combination of the silica and alumina with the lime. A considerable quantity of either or both of these alkalies would probably have the effect of making the cement set more quickly, since the experiment of adding to Portland cements the hydroxides of these elements has shown that they produce this result.

The *sulphur* in Portland cement is present in the form of calcium sulphate and in very small amounts as calcium sulphide. It is usually added in the form of gypsum ($CaSO_4 \cdot 2H_2O$) in order to retard the set. Part of the sulphur present may have been originally in the raw materials, but the amount derived from this source is generally small, most of it going off with the kiln gases in the form of SO_3.†

The amount of *calcium sulphate* permitted by the standard specifications is below 3 per cent., or, in other words, on analysis the cement must not show over 1.75 SO_3. This is added to Portland cement after it has been burned. In quantities below 3 per cent. the effect is beneficial, increasing both the strength and soundness of the cement. If the calcium sulphate exceeds 4 to 5 per cent. the effect is to give high short-time tests, though on the final strength test these larger amounts are found to be injurious.

The quantity of *water* and *carbon dioxide* in freshly made Portland cements is usually very small. During the process of burning both these substances are nearly or entirely driven off, and the amount remaining rarely exceeds and usually is considerably less than 1 per cent. However, as the cement is stored and allowed to season as much as 3 to 4 per cent. of carbon dioxide (CO_2) and water (H_2O) are spontaneously borrowed from the air. This relatively small amount of carbonation and hydration that occurs during the "aging" of the cement is beneficial.

The specifications place no limit on the percentage of combined water and carbon dioxide. This is because the loss on ignition gives no decisive

* Ibid., p. 30.
† Meade, R. K. Portland Cement, p. 124.

indication regarding the quality of the Portland cement, since both the carbon dioxide and the water pass off at a temperature below that of incipient fusion of the raw materials. The mass may be, therefore, under-burned and still give an ignition as low as that of a cement that has been burned sufficiently.

A complete analysis of a Portland cement will often disclose the presence of *other substances* besides those that have been mentioned. Among these are Phosphorous pentoxide (P_2O_5), Titanic oxide (TiO_2), Strontium oxide (SrO), Ferrous oxide (FeO), and Manganous oxide (MnO). They occur, however, in the commercial cements in such small amounts as to be negligible quantities, and have practically no effect on the hydraulicity or the setting properties of the cements.

When Titanic oxide (TiO_2) is present it acts like the silica for which it could probably be substituted, but not profitably, because of the greater heat that would be required to make the raw materials clinker. Manganese oxide acts, on the other hand, as a flux and, like the ferric oxide, assists in the formation of the clinker. Strontium oxide bears somewhat the same similarity to lime as the magnesia, and so when a small amount of strontium oxide is present it is not deleterious, but on the contrary acts as a base and unites with silica and alumina, and combines with ferric oxide just as lime does.

RAW MATERIALS FOR PORTLAND CEMENTS.

All the essential constituents of Portland cement are found in nature in the uncombined form as minerals, except lime, which is always combined with some other substance. Lime (CaO) combines with carbon dioxide (CO_2), forming calcium carbonate ($CaCO_3$), which occurs most abundantly as limestone. Silica (SiO_2) occurs as quartz and alumina (Al_2O_3) as corundum, while ferric oxide (Fe_2O_3), as hematite, is a prominent iron ore. Quartz is one of the chief rock-making minerals, and in the form of sandstones and quartzites occurs as a large and conspicuous part of entire mountain ranges. Quartz occurs in nature far more abundantly than hematite, and the latter in turn is much more

abundant than corundum, which is noted chiefly for its hardness, and in which respect it is second only to diamond. But because of its hardness and the difficulty of grinding, corundum is never used in cement making, and quartz and hematite are only used in very small quantities. Quartz is sometimes introduced in the form of sand or its equivalent, finely ground sandstone, to make up for a deficiency of silica in one or both of the raw materials. Small quantities of iron ore are occasionally employed for the same reason, and for the additional purpose of making a cement especially adapted for marine work.

Silica (SiO_2), alumina (Al_2O_3), and ferric oxide (Fe_2O_3), especially the first two, are essential constituents of all clays and shales and slates. They are present in greater or less quantity and more or less chemically combined, and intimately mixed mechanically in all argillaceous materials, which are so-called in reference to this fact. These argillaceous materials, such as the different varieties of clays, shales, and slates are the chief source for the silica (SiO_2), alumina (Al_2O_3), and ferric oxide (Fe_2O_3) that enter into Portland cement manufacture. On the other hand, limestone, of which there are a number of varieties, is the principal source of the lime (CaO) used.

The materials from which Portland cement is made may be divided into two major groups. The materials in which calcium carbonate is the principal constituent would be classified as calcareous, while those in which the clayey substances, silica, and alumina, are most abundant would fall under the head of argillaceous. In nature calcareous materials are found in which silica and alumina and other impurities are practically absent. There are shales and slates, on the other hand, which, if not quite, are almost wholly free from calcareous constituents. These and the pure limestones represent the extremes, between which lie calcareous shales and argillaceous limestones, which grade one into the other. When the latter is equal to or exceeds 18 per cent. in silica and alumina, it may be considered either as an argillaceous limestone or an extremely calcareous shale, but it is usually given a new name and is called "cement rock." It is customary to classify the cement rocks with the argillaceous materials.

Grouped under the head of calcareous and argillaceous for the reasons above assigned, we have the following materials: *

CALCAREOUS MATERIALS.		ARGILLACEOUS MATERIALS.
Limestones,	Cement Rock.	Clay,
Marls,		Shale,
Chalk,		Slate,
Alkali waste.		Blast furnace slag.

Calcareous Materials.

In the manufacture of Portland cement *limestone* may be combined or mixed with either clay, shale, slate, blast-furnace slag, or cement rock, and a suitable mixture obtained, provided the raw materials used are of the correct composition. The same is true of the marls, chalk, and alkali waste. Over 55 per cent. of the Portland cement manufactured in the United States is made in the Lehigh district by burning a mixture of limestone and "cement rock." In Michigan, Ohio, Indiana, and central New York the calcareous material used is marl, and this is mixed either with clay or shale, and the cement made according to the wet process, the mixture being introduced into the kilns in the form of a slurry. One plant in Michigan † formerly used caustic soda waste and clay; and in the iron manufacturing districts of Pennsylvania and Illinois the slag from blast furnaces is employed and mixed with limestone.

Outside of the Lehigh district, and the exceptions noted, a combination of more or less pure limestone and shale is the basis of the industry. These are the materials which are used by the Security Cement and Lime Company at their plant near Hagerstown, the first of the kind to be built in Maryland, and are also the ones to be employed by the Tidewater Portland Cement Company, at Union Bridge, Md.

Limestones and shales are widely distributed, and for this reason they are destined to be used in the manufacture of Portland cement even more extensively than at present. As the industry develops in Maryland they

* Meade, R. K. Portland Cement, p. 33.
† Meade, R. K. Portland Cement, p. 34.

will be the raw materials upon which the manufacturer will be chiefly dependent.

Calcium carbonate ($CaCO_3$), which in the crystalline form is known as calcite, is the chief constituent of limestones. When the carbon dioxide is driven off from $CaCO_3$, 56 per cent. of the carbonate is left in the form of lime or calcium oxide (CaO). Limestones containing this percentage of lime, however, are exceeding rare. They are usually contaminated by such *impurities* as silica, alumina, iron, and magnesia. The last named of these four varies in amount in limestones from 0 to 21.74 per cent. When this upper limit is reached the chemical composition of the stone is expressed by the formula $CaCO_3 \cdot MgCO_3$ and is called dolomite, which contains 54.35 per cent. calcium carbonate and 45.65 per cent. magnesium carbonate.

Of the four principal impurities in limestones, *magnesia* is the most objectionable and the bane of the Portland cement manufacturer. If this substance occurs in quantities exceeding 5 to 6 per cent. the limestone becomes unsuited for use in the manufacture of Portland cement, though it may be entirely acceptable for the manufacture of lime and for other purposes. More limestones are rejected on account of the magnesia content than for any other cause. The lower, therefore, the content of magnesia the better.

The impurities, besides magnesia mentioned as occurring in limestones, are *clayey matter,* including silica, alumina, and iron. Limestones contain other impurities than these, but they occur in very small percentages, and are therefore in general negligible quantities. The percentage of iron is usually less than that of the alumina, and the sum of these two generally is less than the percentage of silica. All three are land-derived materials and owe their presence in the limestones to the fact that they were carried in suspension out to sea and were deposited, and became mixed with the calcareous muds of the latter in the form of fine silt.

The proportion in which these three substances can occur, making the limestone, so far as they are concerned, ideally suitable for manufacture into Portland cement, is when the percentage of silica equals

at least twice the sum of the percentages of alumina and ferric oxide, and the ratio of silica and alumina is between 2½ and 4 to 1. Then, if these ratios are preserved and these clayey materials amount to 20 per cent. of the limetone, as against a content of approximately 75 per cent. of calcium carbonate, the limestone may, without the addition of further ingredients, be made directly into Portland cement.

Argillaceous limestones with the proportions of the constituents exactly as postulated above are comparatively rare. There are limestones, however, which very closely approximate the composition just described. They are not widely distributed, being chiefly confined to the Lehigh district of Pennsylvania and New Jersey, where they are known as "cement rocks," and furnish the raw material for over 55 per cent. of the Portland cement annually manufactured. Rocks closely similar in composition are also used in the West, in the states of Utah, California, and Colorado.

These limestones, and particularly the "cement rocks" of the Lehigh district, furnishing as they do the raw materials for more than half of the cement made in the United States, are worthy of a more detailed description than can be given at this point of the discussion. Their distribution, physical characteristics, and chemical composition will, therefore, be taken up later.

Silica occurs in limestone without alumina in three distinct forms. It may occur in the form of nodules of chert or flint, or in irregular veins as quartz. When a limestone contains silica in either of these forms it seriously affects the regularity of the composition of the stone and makes it practically useless for cement manufacture. Again silica may occur in a very finely divided condition and evenly distributed through the limestone, and some of it may be in the form of hydrate of silica. When this is the case it combines very readily with the lime, even though alumina be absent. And, finally, it occurs as a constituent of silicates like tremolite and diopside. This third method of occurrence is principally in the more metamorphosed limestone, the crystalline limestones, and marbles, but chiefly in the latter.

When *silica and alumina* occur in metamorphosed limestones they are

found combined about as they were in the clay or silt through which they were first introduced. But the same limestone, if it is considerably argillaceous after undergoing metamorphism, might have an entirely different value for cement making. For, as one of the results of metamorphism of argillaceous limestone, complicated silicate compounds are formed in which are combined both the silicon and aluminum with calcium and magnesium. In the kiln these may prove more or less inert and intractable and render the material useless. It is a matter, therefore, of the utmost concern to the Portland cement manufacturer to have the silica and alumina in the limestone properly combined, and to know in just what manner these two substances are united. The form in which they are most desired is as simple silicates of alumina more or less hydrated and finely divided and widely and evenly distributed throughout the mass. In this form the silica and alumina of the limestone, under the influence of heat, combine most readily with the lime, forming those compounds that give Portland cement its hydraulic properties. Hence it is that argillaceous limestones are much used and are considered an excellent basis for Portland cement manufacture.

Iron occurs in limestones in several different forms. It may occur as a carbonate ($FeCO_3$) siderite, as an oxide (Fe_2O_3) hematite, or as a sulphide (FeS_2) pyrite, and also in the crystalline limestones as a constituent in complicated silicates. It occurs commonly, however, in the form of hematite or pyrite. When the latter is present in an amount exceeding 3 per cent. the quality of the stone is seriously affected. On the other hand, the amount of ferric oxide must not be so high as to cause the ferric oxide in the cement * to be more than 4 per cent. But within these limits the presence of iron is advantageous. It acts like alumina only more effectually in promoting the clinkering of the materials and in aiding silica to combine with lime.

Among the usually negligible impurities that occur occasionally, but seldom in sufficient quantities in a limestone to have a deleterious effect, are the *alkalies and sulphur*. The former, that is, soda and potash where

* Geol. Survey of Ohio, Bull. 3, p. 226.

present, usually occur in loose-textured limestones. In amounts not over 5 per cent. they are not injurious; for then they are easily volatilized by the heat of the kiln and largely driven off with the other kiln gases. But when soda and potash exceed this limit they are apt to have injurious effects on the finished product, and the limestones, therefore, in which they are contained in amounts much over 5 per cent. are to be avoided. Limestones may contain sulphur combined as lime sulphate or gypsum ($CaSO_4 \cdot 2H_2O$) in considerable amounts without causing the limestone to be rejected, and cements have been successfully made from limestones containing 4 to 5 per cent. SO_3.

The amounts of the different impurities that a limestone can contain and still remain suitable for mixing and manufacture into Portland cement may be very briefly summarized as follows:

1. The content of magnesium carbonate should not exceed 5 per cent. (or 6 per cent. where the shale to be used with it is low in magnesia), and the lower the magnesia the better. The amount in the limestone, in other words, should not be high enough to cause the magnesia in the finished product to be more than 4 per cent. This means not above 2.66 per cent. in the mixture of shale and limestone.

2. The amount of silica and alumina present should, unless present in small quantity, be in the proportion of approximately 3 of the former to 1 of the latter. However, this is not absolutely necessary, for the composition of the raw materials should be such that a slight defect here could be corrected in the mixture of limestone and shale. In a word, neither the percentage of silica nor the percentage of alumina in the limestone should be so high in the one case or so low in the other as to disturb the proper ratio that should exist between the two in the finished product.

3. The amount of ferric oxide should not be so high as to cause the amount of ferric oxide in the cement to exceed 4 per cent. except in the case of a Portland cement especially made for marine work.

4. The sum of the percentages of soda and potash, the alkalies, should not exceed 5.

5. Sulphur should be preferably low, but may even exceed 5 per cent.

6. The limestone should be fine-grained and the contained impurities should be evenly distributed which would, if this were the case, consequently give it a uniform composition.

While it is well to bear in mind the points mentioned above with regard to the impurities occurring in limestones, still it must be remembered that a limestone may fail to meet any one of the requirements just mentioned and yet be employed in the manufacture of Portland cement when used in combination with a shale that may occur nearby which supplies to the limestone what the latter lacks. Both the shale and the limestone would be abnormal but together would form a normal mixture. The proper mixture after all is the thing sought.

The second source of calcareous material, far less important than the limestone, is the *calcareous marls*. By origin and composition these fall into two groups designated according to their origin as marine and fresh-water marls. The only marls found in Maryland are of marine origin.

The marine marls, because of their contained impurities, including phosphatic matter and glauconite, are, as a rule, though not always, unsuited for use in the manufacture of Portland cement. The term marl, as used in the Portland cement industry, applies only to the fresh-water marls. These marls occur chiefly in the glaciated regions of the United States in lenticular or basin-shaped deposits of relatively small size. They consist essentially of calcium carbonate in which the impurities, silica, alumina, and iron generally occur in small quantities.

ANALYSES OF MARLS.

	Fresh Water Range*	Marine of Maryland Range.	Marine of Maryland Average
Silica (SiO_2)	1.40- 8.60	17.00-90.00	65.20
Alumina (Al_2O_3)	0.55- 1.30	0.07-10.50	4.40
Iron oxide (Fe_2O_3)	0.25- 1.54		
Lime (CaO)	54.60-46.20	3.64-42.73	20.70
Magnesia (MgO)	1.25- 2.78		
Carbon dioxide (CO_2)	42.90-36.30	2.86-33.57	9.70
Organic matter	0.05-10.50		

* Eckel, E. C. Cements, Limes, and Plasters, p. 343.

The analyses of the fresh-water marls used in this country show a high content of lime and a relatively low content of magnesia, silica, iron, and alumina. In steady practice, however, there is sometimes a considerable range in composition. This is well brought out by the analyses above (p. 293).

The analyses of fresh-water marls were compiled from material used by a prominent plant in Michigan, computed to a dry basis. As the marl comes to the plant it contains 55 per cent. or so of moisture. The analyses having been made on a dry basis, this water content in the original material is, therefore, not given. The marine marls are represented by 30 analyses from different sources in Maryland. The wide divergence in composition of the marine marls of Maryland from the fresh-water marls of Michigan clearly indicate that they are not at all suited to furnish the calcareous material for the manufacture of Portland cement. As a source of argillaceous material bearing some lime they might be mixed with the purer limestones of the adjacent Piedmont, but their low average tenor of alumina makes even such use limited to very few localities.

Cement Rock.

When the formation of limestone is in progress the fine calcareous mud, made up of shells and the comminuted tests of organisms secreting calcium carbonate, may become contaminated by clayey matter derived from the land. As a result of the terrigenous mud thus introduced and mixed with the limey mud or ooze of the accumulating limestone, materials are assembled, constituting what are known as argillaceous limestones. When the content of clayey matter equals or exceeds 20 per cent. the rock is called a "cement rock." The best known example of this is the Trenton limestone which enters into the manufacture of more than half of the Portland cement made in America, and is typically exposed and worked in the Lehigh cement district, which includes the counties of Berks, Lehigh, and Northampton in Pennsylvania, and Warren in New Jersey. The ideal material for making Portland cement is an argillaceous rock composed of approximately 20 per cent. of clayey

matter and 75 per cent. of calcium carbonate. A rock of this sort might be ground and burned and made directly into Portland cement without the admixture of any other material. A rock approaching, but not reaching, this ideal composition would, however, require the addition of pure limestone or the admixture of clayey materials, depending on whether the "cement rock" happened to be either low in calcium carbonate or low in its content of silica and alumina and ferric oxide.

Because of their softness these "cement rocks" are more easily and cheaply pulverized than the hard limestones and, moreover, form a clinker at lower temperature than mechanical mixtures of the same composition. The manufacturer using them effects, therefore, a saving both in the grinding of the raw material and in the consumption of fuel.

In the Lehigh district, where that portion of the Trenton "cement rock" * is typically exposed, it has a thickness of about 600 feet. Here it lies between a shale and a massive and more magnesian limestone. The former is known geologically as the Hudson or Martinsburg shale, and the latter as the Kittatinny limestone. The argillaceous limestone, called "cement rock," lying between the two represents a condition of shallow-water deposition during the Trenton, and like the accompanying formations is of Ordovician age. Toward its top this Trenton limestone becomes more siliceous, like the superjacent shales, while toward the bottom the lime content increases and it becomes more calcareous. In a single quarry, therefore, the beds will generally vary from argillaceous at the top to less argillaceous at the bottom.

The argillaceous "cement rock" of the Lehigh district, as may be inferred from the foregoing, is very dark gray in color and shows a characteristic slatey structure. It ranges in composition from 60 to 80 per cent. of calcium carbonate and 15 to 30 per cent. of clayey matter, and contains from 3 to 5 per cent. of magnesian carbonate. In the manufacture of cement it is generally mixed with the purer limestones

* The "cement rock" corresponds to the Chambersburg and the Kittatinny as here used to the Beekmantown and lower members of the Shenandoah group as these formations are developed in Maryland.

of the district, the right amount of the former to be added, being calculated approximately by the following formula: *

1. Quantity of limestone$=\frac{75-\text{per cent. } CaCO_3 \text{ in cement rock}}{(\text{per cent. } CaCO_3 \text{ in limestone})-75}\times 100$, or, if desired to make the calculation on the basis of the lime (CaO) content, multiply the percentages of $CaCO_3$, of the analyses by .56, and substitute the values in formula 2.

2. Quantity of limestone necessary$=\frac{42-(\% \, CaO \text{ in cement rock})}{(\% \, CaO \text{ in limestone})-42}\times 100$.

Either of these formulas will give the amount of limestone to be added to every 100 pounds of cement rock to make the mixture approximately correct. The analyses following are fairly typical of the composition of the better grade of cement rock and the limestones of the Lehigh district with which they are mixed.

ANALYSES OF CEMENT ROCK.*

	Cement rock.			Limestone.	
	1	2	3	1	2
Silica (SiO_2)	14.08	16.10	13.88	3.02	1.98
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	7.50	2.20	6.58	1.90	0.70
Calcium carbonate ($CaCO_3$)	73.12	76.23	75.75	92.05	95.15
Magnesium carbonate ($MgCO_3$)	4.56	3.54	2.70	3.04	2.03

* Analyses 1 and 3 Cement Rock, Fred. P. Peck, Economic Geology, Vol. III, p. 50.

;Analyses 2 Cement Rock and 1 and 2 Limestone, Ala. Geol. Survey, Bull, 8, p. 24.

Calcium carbonate may be converted to the equivalent per cent. of lime by multiplying the percentage given by .56. Also $MgCO_3$ may be expressed as MgO by multiplying the per cent. of $MgCO_3$ by 47.6.

Analysis 3 of cement rock is of an argillaceous limestone that could be burned directly into Portland cement without the admixture of either lime or shale.

Argillaceous Materials.

The principal argillaceous materials used in cement manufacture are clays, shales, and slates which have been derived from the decay of

* Meade, R. K. Portland Cements, p. 38.

various types of both igneous and sedimentary rocks. They are similar chemically but different in their physical character. As regards chemical composition the clays are much more irregular than either the shales or slates. Clays are composed of fine-grained, only partially consolidated, sediments which, when wet, possess the property of plasticity. These clayey sediments, of which shale and slate are indurated representatives, consist essentially of silica and alumina with accessory iron and other substances in small and varying amounts.

CLAYS.—Clays are formed in many ways and may be classified according to their origin, the more important kinds for cement manufacture being transported, residual, and glacial.

Transported clays consist of land debris which has been moved along mechanically by frost and water to stream bottoms and ultimately to the floor of the sea where they accumulate through the failure of the moving agents to transport them. Such clays are divided into alluvial clays, deposited along the banks of streams, and sedimentary clays laid down in shallow water along the sea coast.

Residual clay, aside from a small percentage of humus and transported material admixed with it at and near its surface, is derived for the most part from the decay of the solid rock upon which it rests. Its thickness, nature, and extent depend upon both the composition and physical character of the underlying rock and the amount and regularity of disintegration brought about by the various natural agencies that are constantly at work.

Glacial clays are absent in Maryland but are found in most of the northern states. They were formed under and about the front of glaciers and deposited in and along the banks of streams fed chiefly by the melting of glacier ice. To the manufacturer of Portland cement, however, they are not of very great interest because they are generally wanting in physical homogeneity and chemical uniformity.

Of the classes of clays that have been mentioned the transported clays are by far the most important. They are more uniform in composition than the residual clays and also are finer in grain and more homogeneous physically. The residual clays, no matter from what sort of rock they

are derived, generally contain, scattered through their mass, pieces of undecomposed rock of different sizes. The residual clays derived from limestones generally contain nodules of chert and small pieces of undecomposed calcium carbonate, while those derived from granite, for instance, are more likely to contain difficultly fusible minerals like quartz.

The difference in composition of the transported and residual clays is due to the difference of origin and to the further fact that the transported clays are derived largely from the residual clays. The former contain finer and more uniform particles resulting from the reworking of the residual clays into branches, creeks, and rivers, and the subsequent separation of the coarse and fine material by the sorting action of running water.

A clay to be suitable for use in the manufacture of cement should be homogeneous physically, fine-grained, and of correct and uniform composition throughout. The presence of sand and of nodules of various sorts, particularly flint and quartz, if present to any considerable extent, are extremely objectionable and may make an otherwise acceptable deposit altogether worthless.

The clay for Portland cement manufacture should contain at least 55 per cent., but preferably between 60 and 70 per cent., of silica. It should be low in magnesia and alkalies, preferably not over 3 per cent., and low in sulphides or sulphur. Clays may often contain considerable magnesia without rendering them unfit for use in cement manufacture, particularly when they are to be used with limestones low in magnesia. They should not contain too much iron, and usually this should not be more than one-third of the alumina. The sum of the percentages of alumina and iron should not be more than one-half the percentage of silica, and the clay will usually be better the nearer the percentage ratio $\frac{SiO_2}{Al_2O_3+Fe_2O_3}=3$ is approached.

Clays are divided into "normal" and "limey" clays according to their content of magnesia (MgO) and lime (CaO). If the sum of these oxides exceeds * 5 per cent. the clay is called a limey clay, and if it

* Eckel, E. C. Cements, Limes, and Plasters, p. 354.

contains less than 5 per cent. of lime and magnesia it is referred to as a normal clay. Below are given a number of analyses of both normal and limey clays actually used in Portland cement manufacture:

ANALYSES OF NORMAL AND LIMEY CLAYS USED IN THE MANUFACTURE OF PORTLAND CEMENT.

	Normal Clays.*			Limey Clays.		
	1	2	3	1	2	3
Silica (SiO_2)	53.30	63.82	57.25	55.27	47.45	61.70
Alumina (Al_2O_3)	23.29	25.36	26.15	10.20	19.85	18.00
Ferric oxide (Fe_2O_3)	9.52			3.40		
Lime (CaO)	0.36	3.42	3.09	9.12	17.80	8.40
Magnesia (MgO)	1.49	n. d.	1.10	5.73	0.09	2.91
Alkalies ($K_2O + Na_2O$)	n. d.	n. d.	1.88	n. d.	4.34	n. d.
Sulphur Trioxide (SO_3)	n. d.	n. d.	0.39	n. d.	1.03	n. d.
Carbon dioxide (CO_2)	n. d.	6.96	9.30	n. d.	n. d.	13.30
Water (H_2O)	n. d.			n. d.	n. d.	
$\frac{SiO_2}{Fe_2O_3 + Al_2O_3}$	1.62	2.52	2.19	4.06	2.39	3.43

Normal Clays:
1. White Cliffs Portland Cement Company, White Cliffs, Arkansas.
2. Peninsular Portland Cement Company, Cement City, Michigan.
3. Pacific Portland Cement Company, California.

Limey Clays:
1. Sandusky Portland Cement Company, Syracuse, Indiana.
2. Buckeye Portland Cement Company, Harper, Ohio.
3. Wabash Portland Cement Company, Stroh, Indiana.

* Eckel, E. C. Cements, Limes, and Plasters, p. 355.

SHALES AND SLATES.—*Shales* and *slates* have, as has been noted, essentially the same composition as clays, that is, the chief and important constituents are silica, alumina, and iron, with varying small amounts of other substances. Except in the manufacture of Portland cement from marls by the wet process, shales and slates are, on the whole, preferred to clays, even though they are harder.

Like the clays, both shales and slates vary widely in chemical composition, but within a limited area they show as a general rule a much greater homogeneity than clays do, and also much more uniformity in chemical composition. This is due primarily to their difference in origin.

The hardness and fissility, characteristic of shales, are due to the pressure to which the original unconsolidated clayey sediments were subjected subsequent to their deposition. The same sort of sediments, as the result

of metamorphism, may be changed to slates which differ from the shales not only in their greater and more perfect fissility, but in the further fact that the cleavage is a secondary property which may or may not be parallel to the planes of stratification.

Because of their wider occurrence and their more favorable situation, with respect to limestones, shales are far more extensively used in Portland cement manufacture than slates.

The term shale, as popularly used, refers to a rock with more or less marked cleavage, fine-grained and uniform in composition, consisting essentially of silica, alumina, and iron, in variable proportions. For example, there are shales high in silica, the so-called siliceous shales, and then again there are those high in iron and alumina, etc., besides which there are also calcareous shales, containing an exceptional amount of lime, and carbonaceous shales characterized in certain exceptional instances by the presence of as much as 12 to 14 per cent. of carbon.

Shales, however, to be used in the manufacture of Portland cement must meet certain clearly defined specifications with regard to chemical composition. These are briefly enumerated as follows:

They should be preferably low in magnesia, and should not exceed in any case an amount which would cause the content of magnesia in the cement to be greater than 4 per cent.

The ratio of silica to alumina should be between 2.5 to 1 and 4 to 1.

The content of sulphur should be preferably low, not exceeding 5 per cent.

The shale should also contain at least 3 per cent. of ferric oxide for fluxing purposes, but not enough to cause the ferric oxide in the cement to exceed 4 per cent. The nearer the ratio

$$\frac{SiO_2}{Al_2O_3+Fe_2O_3}=3$$

is approached the better is the quality of the shale. There should be at least 55 per cent. of silica, but preferable between 60 and 70 per cent.

To clays or shales which are slightly low in silica and high in alumina the ratio between the two may be corrected often by the addition of small amounts of finely ground sandstone or sand. Likewise if it is

slightly low in ferric oxide this may be added in the form of the iron ore, hematite.

The shale may be absolutely abnormal, however, and still prove satisfactory if the limestone with which it is to form a mixture has such a composition that in its abnormality it supplements and remedies the defects in the shale or slate, the two forming a normal and correctly proportioned mixture fit for burning into Portland cement.

Below are given the analyses of some of the shales used in different American cement plants, including the normal shales, where the sum of the lime and magnesia is less than 5 per cent., and the limey shales, where the content of the two is higher than the figure just mentioned:

ANALYSES OF SHALES USED IN THE MANUFACTURE OF PORTLAND CEMENTS.

	Normal Shales.*				Limey Shales.			
	1	2	3	4	1	2	3	4
Silica (SiO_2)	60.00	59.64	65.99	54.70	53.12	57.45	57.50	53.63
Alumina (Al_2O_3)	23.26	19.14	21.57	31.68	20.60	20.56	21.70	24.47
Ferric oxide (Fe_2O_3)	4.32	7.59	6.07		4.09	2.78		
Lime (CaO)	0.90	0.26	0.47	1.15	4.02	4.27	12.19	5.94
Magnesia (MgO)	1.12	2.31	0.82	n. d.	2.24	3.17	1.93	1.79
Alkalies ($K_2O \cdot Na_2O$)	n. d.	4.33	n. d.	n. d.	....	....	....	....
Sulphur trioxide (SO_3)	n. d.	n. d.	n. d.	n. d.	n. d.	0.35	n. d.	n. d.
Carbon dioxide (CO_2)	6.16	4.71	n. d.	n. d.	13.70	8.15	n. d.	10.03
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$	2.14	2.23	2.38	1.72	2.15	2.45	2.65	2.19

1. Ironton Portland Cement Company, Ironton, Ohio.
2. Lehigh Portland Cement Company, Mitchell, Indiana.
3. Crescent Portland Cement Company, Wampum, Pa.
4. Hudson Portland Cement Company, Hudson, N. Y.

1. Chicago Portland Cement Company, Oglesby, Ill.
2. Alpena Portland Cement Company, Alpena, Mich.
3. Cayuga Portland Cement Company, Portland Point, N. Y.
4. Virginia Portland Cement Company, Craigsville, Va.

* Eckel, E. C. Cement, Limes, and Plasters, p. 357.

LOCATION OF A PORTLAND CEMENT PLANT.

The following factors have to be considered in locating a cement plant or any industrial enterprise dependent on the use of either limestone or shale, or the use of them both together:

1. Location of deposit, with respect to transportation routes and markets.
2. Amount of material available.
3. Chemical composition of material.
4. Fuel supply.

Location with Respect to Transportation Routes and Markets.

One of the first factors influencing the location of a proposed cement plant is its relation to transportation routes and markets. Unless the proposed site is near a railroad or water route along which the necessary raw materials and finished products may be moved economically all profits of manufacture are likely to be absorbed in meeting the prices of competing concerns more favorably situated. To acquire satisfactory freight rates it is necessary to select sites near friendly transportation lines or where low rates may be secured through the competition of rival carriers. The distance from large and well-established markets is another prime factor, since for its value Portland cement is a heavy and rather bulky commodity. The margin between cost of manufacture and selling price may easily be absorbed by the increased freight charges involved in long haulage.

Location with Respect to Raw Materials.

In searching for a limestone intended for the manufacture of Portland cement, a great amount of preliminary information may be had from the reports that have been issued by the Maryland Geological Survey and the Federal Government. The prospector before starting out should obtain, therefore, all the data available from these sources and take into the field, provided they are to be had, both topographic and geological maps of the region in which suitable material is sought. The geological maps will show the areal distribution of formations, and the reports will give their thickness and more or less information as to the quality of the materials of which they are composed. The maps will further show the relations of shales and limestones which should occur near one another, and the occurrence of both with regard to water, transportation facilities,

etc., and distances from the leading markets. From these facts the investigator, be he a geologist, mining engineer, or even an untrained prospector acting for himself, or another, may decide in what particular district it would probably be best to locate and where detailed work may be pursued with the best chances of finding sufficient material of a composition suitable for the purpose.

One can hardly expect, however, to find in geological reports the detailed information as to the quantity and the quality of material occurring within the limits of any particular property. The presentation of the facts in these reports must necessarily be more or less general. Information of the sort that is required before the investor would be justified in making a purchase must be had, therefore, by employing either a first-class geologist, chemist, or mining engineer, to make an examination and render an opinion, together with the facts upon which it is based.

DETERMINATION OF QUANTITY.—In determining the available quantity of limestone or shale the first step is to measure its thickness, not along the surface of outcrop, but along a line perpendicular to the planes of stratification, or, in other words, perpendicular to the direction of dip. In Figure 17, for instance, the limestone is overlain by shale and the direction of the dip is represented by the line *EH*. The thickness should, therefore, be measured along the line *EG*, which is equal to the sum of the thicknesses of the individual beds between *G* and *H*. The thickness of the limestone bed represented in Figure 18 is equal to *AB*, less the thickness of the soil covering, but if a ravine or railroad cut should expose the stone along *CD* the thickness would be obtained by measuring along this exposure perpendicular to the bedding; or the same value could be computed by multiplying the distance measured along *CD* by the natural sine of the angle between *CD* and the horizontal. With the thickness thus obtained, and a knowledge of the direction of the strike, it becomes an easy matter to calculate the quantity of material. If, for instance, a limestone bed 200 feet thick outcrops and can be traced for a distance of 2500 feet across a certain property and can be worked to a depth of 100 feet, along the dip the number of available cubic feet of

stone is obtained by multiplying these values. A cubic foot of limestone is taken at 160 pounds, and therefore the value in pounds would be $200 \times 100 \times 2500 \times 160$. This product divided by 2000 would give the value in tons which in this case would amount to 4,000,000 short tons, or enough material to last a five-kiln Portland cement plant for over 50 years, each kiln consuming yearly close to 15,000 tons of limestone. About one-third this amount of shale, or 5000 tons per kiln, would have to be provided for annually to mix and burn with the limestone. In order to have the supply of shale last for as long a period as the limestone, the shale property should contain about 1,500,000 tons of shale, all of which should be, like the limestone, susceptible of economic quarrying. The quantity of shale is calculated as the tonnage of limestone was, with the exception that the shale is estimated as weighing less than the limestone, or from 125 to 130 pounds per cubic foot.

Before a Portland cement plant is located there should be sufficient raw material in sight to ensure an unfailing supply for a period of at least 25 years, estimating the capacity of the plant at from 2000 to 2500 barrels a day. The tonnage of shale and limestone required may be estimated approximately from the table below, taken from "The Lime and Cement Resources of Missouri," by H. A. Buehler. As stated by the author the table was compiled to show "the *approximate* number of acres of shale and limestone required to supply a Portland cement factory having a capacity of 2500 barrels per day." It is obvious, of course, as the compiler of the table observes, that the values given are only and can be only approximate, because of the varying quantity of limestone and shale that enter into different mixtures ready for burning.

As stated elsewhere in this report, both the shale and limestone may be abnormal, and yet mixed in proper proportions with due regard to the chemical composition of each, yield a mixture which would burn to a clinker that may be ground into a cement capable of meeting the most rigid requirements. The figures given in the table below are based on statistics gathered in Missouri where "an average of 132 pounds of shale and 465 pounds of limestone are used to produce a barrel

ACRES OF LIMESTONE AND SHALE REQUIRED FOR A 2500-BARREL PLANT.*

Thickness.	Deposit.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.	40 yrs.	50 yrs.	60 yrs.	75 yrs.	100 yrs.
5 ft.	Shale	36.9	55.3	73.7	92.2	110.6	129.0	147.5	184.3	221.2	276.6	368.7
5 ft.	Limestone	116.0	174.0	232.0	289.9	347.9	405.9	463.9	579.8	695.8	869.7	1159.6
10 ft.	Shale	18.4	27.7	36.8	46.1	55.3	64.5	73.7	92.2	110.6	138.3	184.3
10 ft.	Limestone	58.0	87.0	116.0	141.0	173.9	203.0	232.0	289.9	347.9	434.9	579.8
15 ft.	Shale	12.3	18.4	24.6	30.7	36.9	43.0	49.2	61.5	73.7	92.2	122.9
15 ft.	Limestone	38.7	58.0	77.4	96.7	116.0	135.3	154.7	193.3	232.0	289.9	386.6
20 ft.	Shale	9.2	13.8	18.4	23.1	27.7	32.2	36.9	46.1	55.3	69.2	92.2
20 ft.	Limestone	29.0	43.5	58.0	72.5	87.0	101.5	116.0	145.0	173.9	217.5	289.9
25 ft.	Shale	7.4	11.1	14.7	18.4	22.1	25.8	29.5	36.9	44.3	55.3	73.7
25 ft.	Limestone	23.2	34.8	46.4	58.0	69.6	81.2	92.8	116.0	139.2	173.9	232.0
30 ft.	Shale	6.1	9.2	12.3	15.4	18.4	21.5	24.6	30.7	36.9	46.1	61.5
30 ft.	Limestone	19.4	29.0	38.7	48.4	58.0	67.7	77.4	96.7	116.0	145.0	193.3
40 ft.	Shale	4.6	6.9	9.2	11.6	13.8	16.1	18.4	23.1	27.6	34.8	46.1
40 ft.	Limestone	14.5	21.8	29.0	36.3	43.5	50.8	58.0	72.5	87.0	108.8	145.0
50 ft.	Shale	3.7	5.5	7.4	9.2	11.1	12.9	14.7	18.4	22.1	27.7	36.9
50 ft.	Limestone	11.6	17.4	21.2	29.0	34.8	40.6	46.4	58.0	69.6	87.0	116.0
60 ft.	Shale	3.1	4.6	6.1	7.7	9.2	10.8	12.3	15.4	18.4	23.1	30.7
60 ft.	Limestone	9.7	14.5	19.4	24.2	29.0	33.9	38.7	48.4	58.0	72.5	96.7
70 ft.	Shale	2.6	4.0	5.3	6.6	7.9	9.2	10.6	13.2	15.8	19.8	26.3
70 ft.	Limestone	8.3	12.9	16.6	20.7	24.9	29.0	33.2	41.4	49.7	62.2	82.8
80 ft.	Shale	2.3	3.6	4.6	5.8	6.9	8.1	9.2	11.6	13.8	18.4	23.1
80 ft.	Limestone	7.3	10.9	14.5	18.2	21.8	25.4	29.0	36.3	43.5	58.0	72.5
90 ft.	Shale	2.0	3.1	4.1	5.1	6.1	7.2	8.2	10.3	12.3	15.4	20.5
90 ft.	Limestone	6.5	9.7	12.9	16.1	19.4	22.6	25.8	33.0	38.7	48.4	64.5
100 ft.	Shale	1.8	2.7	3.7	4.6	5.5	6.4	7.4	9.2	11.1	13.8	18.4
100 ft.	Limestone	5.8	8.7	11.6	14.5	17.4	20.3	23.2	29.0	34.8	43.5	58.0

* Missouri Bureau of Geology and mines, "The Lime and Cement Resources of Missouri," by H. A. Buehler, Vol. VI, 2d. ser., p. 46.

The area given is for horizontal beds. If the strata are folded or inclined the figures apply to the areas of the respective beds between their surface outcropping and the depth of economical quarrying, since the latter figure seldom exceeds 100 feet the area of surface ground underlain will differ with the inclination of the beds decreasing rapidly with the increase in dip.

of Portland cement." * The weight of a cubic foot of limestone is taken at 168 pounds, and the weight of a cubic foot of shale is taken at 150 pounds. Both these weights appear to be rather high, particularly that quoted for a cubic foot of shale.

The reader is cautioned against putting too much reliance on a table like the above, except as indicated, i. e., to obtain approximate values. The only means of knowing the amount of limestone and shale needed in any particular case is from the chemical composition of both.

Examinations of limestone and argillaceous deposits soon disclose the fact, that when the two are sought for use in the manufacture of Portland cement, it is much more difficult to find deposits of the former having the correct chemical composition than it is to locate a suitable shale. This is because most of the limestones contain more than the permissible amount (5 to 6 per cent.) of magnesia. Limestones low in magnesia are scarce, and large deposits suitably situated and of the proper composition for making Portland cement are rare enough to make them "as valuable as a good iron ore deposit."

When shales and limestones are used in Portland cement manufacture about 75 per cent. of the mixture consists of limestone which is composed essentially of calcium carbonate. If the limestone contains a considerable percentage of clayey matter it may be necessary to add a purer limestone, and conversely, if the limestone is very pure there must be a proportional increase in the mixture of argillaceous limestone or of those materials composed essentially of silica, alumina, and iron, such as clays, shales, etc. In selecting properties to furnish the raw materials for a cement plant, provision must be made for a tonnage of limestone amounting to about three times that of the shale. Thus, to reiterate, limestone is the principal and controlling ingredient of the cement mixture. Therefore, in choosing a site for a cement plant which consumes about three times as much limestone as shale, the first and most important step is to find an area where the limestone of suitable composition is present in abundance. If the limestone and shale should happen

* Buehler, H. A. The Lime and Cement Resources of Missouri, p. 45.

to be some distance apart, the plant should be located on the property containing the former.

DETERMINATION OF QUALITY.—In the search for a property of the sort just mentioned one will encounter property after property where limestone occurs in abundance and suitably situated which is unacceptable because the limestone is too high in magnesia.

That the search for suitable material may progress rapidly and the cost of chemical analyses be lowered to a minimum, it becomes necessary to eliminate such properties as fast as possible. This can be accomplished if some inexpensive and sufficiently accurate method is employed in the field that will indicate the relative content of magnesia in the various limestones encountered.

Limestones containing 15 to 20 per cent. of magnesia may be detected by the fact that when treated with acid they effervesce and give off carbon dioxide (CO_2) less freely than limestones in which the content of magnesia is somewhat less than the amounts mentioned. While this method of determining magnesian limestone is good enough as far as it goes, it fails to go quite far enough. Cement specifications call for limestones in which the magnesia (MgO) content is not over 0.2 to 3.5 per cent. and, therefore, a more accurate method is desirable. Such a field method was worked out by Mr. J. J. Porter, Associate Professor of Metallurgy at the University of Cincinnati, when employed as an assistant in the laboratory of Mr. Charles Catlett, of Staunton, Virginia, and is given below:

FIELD TEST FOR MAGNESIA.

THEORY.

This method is based on the fact that while calcium hydrate is very soluble in a solution of cane sugar, magnesium hydrate is only slightly so. This gives us a means of precipitating magnesia in the presence of lime, obviating the necessity of a tedious preliminary separation of lime.

Iron is removed from the solution by boiling with an excess of pure calcium carbonate by which it is precipitated as a hydrate, so that it can be filtered off with the insoluble matter. If left it would be held in solution by the sugar, but the color would be a disturbing influence. As ammonia salts have a strong solvent action on magnesia hydrate, soda or potash is used as the precipitant, and this also serves the purpose of holding the alumina in solution.

Manganese and zinc, if present in large amounts, will interfere slightly. Their hydroxides are redissolved by soda and sugar, but slowly, and a noticeable turbidity usually remains. Barium also gives a turbidity, probably due, however, to traces of sulphates in reagents. These elements, as well as others which might interfere, rarely occur in more than minute traces in limestone, so that the value of this test for technical work is unaffected.

REAGENTS.

1: 1 Hydrochloric acid. One volume hydrochloric acid of 1.20 specific gravity plus one volume of water.

A 30 per cent. solution of sodium hydrate. Thirty grams of sodium hydrate (pure by alcohol) to 100 cc. of water. This must be free from carbonate.

Sugar solution. A cold saturated solution of granulated sugar.

Calcium carbonate c. p. precipitated.

Standard limestones as needed, powdered to 40 mesh.

APPARATUS.

A small steel mortar for powdering samples.

Small sieve, 40 mesh.

Measuring spoon, holding between .4 and .5 grams of 40 mesh limestone powder, level full.

Twelve test tubes with mark at 10 cc.

Stand to hold 12 test tubes in two rows.

A pipette, 1½ cc., for sugar solution.

A pipette 1 cc., for sodium hydrate.

Six small funnels.

Filter papers to fit, uniform size.

Test tube holder.

Alcohol lamp.

Water bottle.

Test tube brush.

All of the above apparatus may be packed in a small box having inside dimensions of 11″ x 7″ x 7″.

METHOD.

Crush and powder sample in mortar and sift. Pour this powder into a measuring spoon and level off by knife blade or card. Transfer the measured portion to test tube.

Add now from pipette 1¾ cc. of acid, and when effervescence has nearly ceased, boil for a moment. Add next sufficient of the pure calcium carbonate and neutralize the excess acid. Boil until steam issues freely from the mouth of the test tube in order to drive out all the carbon dioxide. Add water to the 10 cc.-mark and mix thoroughly by shaking the test tube.

In another test-tube place by means of the proper pipettes 1½ cc. of sugar solution, 1 cc. of sodium hydrate solution and dilute with water to the 10 cc.-mark. Then filter the solution of the stone allowing the filtrate to run in the alkaline sugar solution. If magnesia is present a precipitate of magnesium hydrate will form at the line of contact of the two solutions, and

after the filter has drained these solutions should be mixed by inverting the test tube.

The density of this precipitate is roughly indicative of the percentage of magnesia in the stone, and by comparison with standard stones run in parallel this percentage can be estimated fairly accurately, the probable error not being greater than 20 per cent. of the amount of the magnesia present.

NOTE AND PRECAUTIONS.

The fineness of the stone affects the weight held by the measuring spoon and also the ease of solution, hence the need of sifting.

There should be sufficient acid to dissolve thoroughly all the carbonates of the stone and this condition is assured if the resulting solution is yellow from ferric chloride. At the same time it is desirable to have the smallest possible excess of acid, since the presence of alkaline chlorides decreases very materially the delicacy of the test.

The object of the calcium carbonate is twofold. It precipitates the iron, and it creates a condition of uniformity as to the neutrality of the solution which is very essential for comparative results.

It is desirable that all the filter papers used in a series of tests be of uniform size and quality of paper, so that they may retain a uniform amount of the stone solution.

The method of adding the reagents is important and it should be closely followed.

Sugar has a much greater influence in preventing the precipitation of magnesium hydrate than in dissolving it after it has formed, and if the sugar be added to the stone solution before the alkali, the delicacy of the test is very much lessened.

After trying all sorts of methods the one given above has been found to give the most satisfactory results, both as to delicacy and reliability.

It is of course essential that the sodium hydrate contain no carbonate, and it should, therefore, be occasionally tested by barium hydrate or by a solution of lime and sugar.

The magnesium hydrate precipitate frequently comes down of a greenish color. The cause of this I have been unable to determine, but it is most prominent in those samples containing carbonaceous organic matter. Possibly it is due to a trace of ferrous iron produced by the carbonaceous matter. This color apparently causes the precipitate to appear somewhat more dense and opaque, and therefore should be allowed for in making comparisons. With a little practice this is not difficult, particularly if the comparison is made by transmitted light.

With the procedure outlined above the best conditions for comparison are obtained from stones ranging up to 4 per cent. magnesia. Percentages above this give a precipitate so dense as to make comparison very difficult and uncertain. Dilution to a larger volume before comparison is of great assistance in these cases, but if much work were to be done exclusively on high magnesia samples, it would be preferable to filter off an aliquot part (one-half or one-fourth) of the stone solution.

Pure limestone, when treated with dilute hydrochloric acid, will disintegrate entirely and pass into solution according to the reaction:

$$\begin{array}{ccccc} \text{limestone} + \text{acid} & = & \text{calcium chloride} & + & \text{carbonic acid} \\ Co_1CO_3 + 2HCl & = & CaCl_2 & + & H_2CO_3 \end{array}$$

The carbonic acid breaks down to water and carbon dioxide. It is this reaction, $H_2CO_3 = H_2O + CO_2$, that causes the effervescence that is observed when limestones are touched by or immersed in certain dilute acids, particularly hydrochloric.

If a splinter of limestone is put into a test tube and effervesces, and then effervescence ceases without dissolving all of the calcium carbonate as a result of a precipitate or coating forming on the splinter, it indicates that if this limestone is used it must be mixed with one higher in its content of calcium carbonate. On the other hand, if all the calcium carbonate is dissolved from the splinter of stone and the latter still retains approximately the outline of its former shape, the limestone is probably very close to being what is commonly known as "cement rock," requiring before burning the addition of very little, if any other, material.

The limestones high in magnesia can be distinguished to a certain extent by their physical appearance. Not only are they slightly harder and less easily weathered than the limestones in which the content of magnesia is low or entirely absent, but on fresh fracture they have a duller luster, a rather saccharoidal texture, and present a coarser, less smooth, and less fine-grained surface. Broadly speaking, the low magnesian limestones (2 to 5 per cent. $MgCO_2$) have a satiny luster, while the luster of the high-magnesian limestones is less marked. This is particularly true of the Shenandoah limestones of the Hagerstown and Frederick valleys, but is a rough diagnostic that is of no value whatever in the Piedmont, where the physical appearance of the limestone is quite different. The limestones of the Piedmont are dominantly white and crystalline, while the Shenandoah are less crystalline and vary in color from blue and gray to a light dove color. The magnesia, when the content in the Piedmont limestone is high, is often evidenced by the

presence of the mica, phlogopite, which is one of the numerous minerals found in crystalline limestones as the result of metamorphism.

SAMPLING AND DRILLING.—The manufacture of cements, particularly Portland cement, is a strictly chemical process, as much so, and in the accuracy of its details almost more so, than the manufacture of iron. Therefore, it is extremely essential that the substances used should have not only a uniform composition, but should have a composition that fulfils all the chemical requirements. Hence, in locating a site for a plant, the materials to be used should be sampled with the greatest care. The whole success of the undertaking depends upon the care and manner and accuracy with which this is done.

The samples should be taken so that every inch of the rock to be employed will be represented in the sample. These should be taken perpendicular to the bedding, though this is not necessary if every bed is sampled at the same angle. However, the first method is easier and accompanied by less danger of error. Samples might be taken by some mechanical means, such as drilling, by which each bed would be samples at the same angle, but in the work of preliminary examinations this would involve a large, and oftentimes unnecessary, expense. If the beds, however, should happen to be horizontal, or approximately horizontal, and not shown anywhere in vertical section on the particular property under examination, then drilling would be the only proper and possible course of getting samples.

There is a widespread impression, however, that every property upon which a cement plant is to be located should be and can only be thoroughly sampled by diamond drilling. This is due largely to the misleading statements that have appeared in many of the various cement company prospectuses, but to a certain extent is due also to the manner in which some writers on the subject have unduly emphasized the accuracy of this particular method of sampling as against all others.

It seems, therefore, not out of place in this connection to show those geological conditions which demand drilling, and those where it is unnecessary, and where a cheaper and sufficiently accurate method may be substituted in its stead.

The two drawings on this page show in the case of Figure 17 horizontal strata, and in the case of Figure 18 strata that have been considerably tilted. The thickness of the limestone in both cases is obtained by measuring perpendicular to the bedding. In general, limestone occupy-

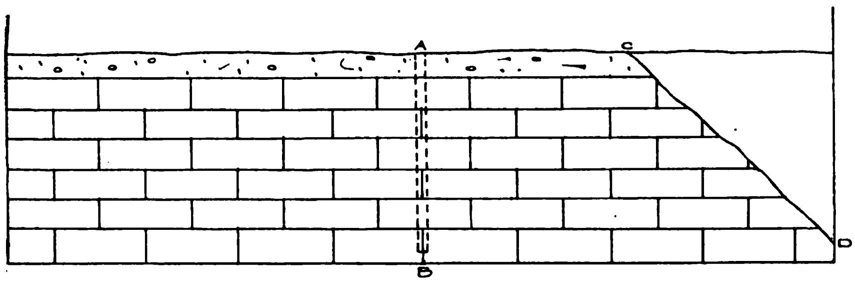


FIG. 17.—Diagram showing method of determining thickness of horizontal beds.

ing the horizontal position shown in Figure 17 could only be sampled by use of the diamond drill, while that inclined and dipping from the horizontal as seen in Figure 18 might be sampled without going to this extra expense.

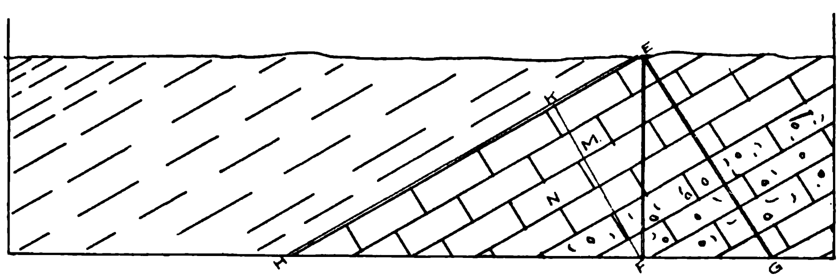


FIG. 18.—Diagram showing method of determining thickness of inclined beds.

The necessity of drilling for samples in horizontal strata only arises when the horizontal strata on a particular property are not shown in vertical section, or where such vertical sections are poorly exposed. The usual vertical section may be furnished by a railroad cut or, to even better advantage, by the erosive agents of nature. A stream cutting through the property might reveal the rock along the line *CD*. A series

of samples taken along this stream-cut section, representing the various beds exposed, would be fairly indicative of the quality of the stone as a whole. Nevertheless it would be advisable and necessary before reaching a final decision to take other samples up and down the stream along sections parallel to *CD,* and at intervals of 30 to 50 feet.

If the chemical constituents of the stone, as exhibited by the analyses made on these samples, showed a very narrow range, and the analyses were otherwise satisfactory, it would lead to a very strong presumption that the stone throughout the property was uniform in chemical composition. A presumption supported by such facts as these is usually borne out by experience, but it is doubtful whether a limited amount of drilling could safely be dispensed with on a property with horizontal strata dissected by only one stream.

In Figure 18 are shown tilted strata dipping at an angle of about 30 degrees. Overlying the limestone is shale, and both are represented in the conventional manner used in geological drawings. Either of the formations could be sampled at the surface by removing strips of such surface covering as may be present in the form of transported or residual soil, provided the overburden is not sufficient to make their subsequent exploitation unprofitable.

Figure 18 illustrates also how a great deal of useless drilling is often done to discover at various depths what may be clearly seen at the surface. For instance, a drill hole sunk along the line *EF* would pass through a stratigraphic thickness equal to *KF*. The bed *F* projects and may be observed at the surface at a distance from *E* opposite to the direction of dip equal to tan $(90 - a)$ *EF*, where a is equal to the angle of dip. It may be observed here that the steeper the dip the less is the stratigraphic thickness gone through for each foot of drilling. When the strata are on end, or dipping at 90 degrees the stratigraphic thickness passed through is, therefore, only equal to the diameter of the drill. In such a case, and numerous instances are known where drilling has been done both on a vertical and approximately vertical strata, the money spent has been absolutely wasted.

Sampling a Portland cement property where the strata are more steeply inclined may be accomplished by the use of a diamond drill, but this entails, as has already been pointed out, a considerable expense. Drilling along the line *EF* the stratigraphic thickness gone through at a depth *F* is equal to *KF* and $KF =$ cosine of the angle *KFE* by *EF*. This same thickness might be just as well sampled by trenching along the surface and sampling perpendicular to the bedding for a distance equal to tan $(90 - a)$ by *EF*.

If the strata should happen to be exposed along the line *GH* samples could and should be taken perpendicular to the bedding at intervals of from 30 to

50 feet, or even closer and parallel to *EG*, which is drawn at right angles to the dip. In other words, under such conditions each individual bed should be sampled. The bed marked *L* might be sampled perpendicular to the bed at the point *L* (see Fig. 18) while stratigraphically and immediately below the bed marked *M* might be hidden by talus or soil. A sample of this bed taken perpendicular to the strata might, however, be had at the point *M* 30 to 50 feet from *L* where the bed *M* happened to be exposed. Likewise, another sample might be taken of the bed *N* at the point *N* and so on at convenient points of each separate bed down to *G*. These samples on analysis would furnish a basis of comparison of the quality of the stone down the dip. Should they prove approximately uniform and show a narrow range in composition, it may be fairly expected that the composition at different intervals along the strike that show a corresponding uniformity, and conversely, samples taken along the strike that show a uniform composition in this direction indicate within reasonable limits a corresponding similarity in uniformity of composition down the dip, for experience has shown that as a rule individual limestone or shale beds will remain uniform in chemical composition within the boundaries of the ordinary cement property. The lack of uniformity in a quarry is found oftenest in the chemical and physical differences of different strata rather than along the strike of a single bed.

Very satisfactory samples can be taken by means of the churn drill. This does not allow small seams and irregularities in the rock to be detected as well as does the core drill. On the other hand, it gives a better average sample of the rock than does the core drill, unless the core is broken up. Sampling with the churn drill can be done for about one-half the cost of the core drill. Where the churn drill is used, the mud which is taken from the drill hole is placed in a tub at intervals, say every 5 feet. The mud in this tub is thoroughly stirred and an average sample of several pounds is taken. This is dried and sent to the chemical laboratory for analysis.

With the churn drill great care must be taken that no surface clay is washed into the hole and also, when clay seams in the rock are drilled through, that material from them is not washed into the drillings.

What has been said about sampling limestones applies equally well to sampling shales and other argillaceous material. In taking samples, however, either of limestones or shales it should be borne in mind that the only samples that are representative or of any value are those which represent the fresh and unweathered rock. With the harder limestones fresh samples may be had very close to the surface, but as the limestones become more argillaceous and softer they are more easily attacked by the agencies of erosion, and the weathered surface has to be removed in order to obtain samples that can be regarded as correctly representative.

*Location with Respect to Fuel Supply.**

In addition to the suitable location of the raw materials with respect to transportation facilities and markets, amount of material, and the chemical composition, the physical character of the materials have to be considered as well as the location of the plant with regard to fuel supplies. With the invention and introduction of improved machinery for grinding, the matter of the physical character of the materials is not so important as it was some years ago. Nevertheless, in Portland cement manufacture, it is obvious that the softer and dryer the material the better, for then it can be more easily excavated and more easily ground and prepared for mixing.

The distance, however, of a Portland cement plant from its fuel supply and the freight rates obtainable from the railroads are seen to be extremely important when it is remembered that every barrel (380 pounds) of Portland cement represents a total consumption in kilns and plant of from 150 to 200 pounds of coal for the dry process or 200 to 250 pounds for the wet, or for a 3000-barrel plant an annual consumption of from 75,000 to 100,000 tons. The fuel consumption is thus seen to represent one of the largest items in cost of manufacture. In most places the average is about 30 per cent. of the total cost of production.

The composition of the coals used in the kilns for burning the Portland cement mixture to incipient fusion should fall within the following limits:

	Per cent.
Volatile matter	30-40
Fixed carbon	50-60
Sulphur	0- 3
Ash	5-25

In other words, they should be bituminous coals high in volatile matter and correspondingly low in fixed carbon. The high-carbon coals, such as anthracite and semi-bituminous coal, give higher temperatures than the bituminous coals, but combustion takes place less rapidly when they are pulverized and blown into the kiln, and accordingly they give less

* The Coals of Maryland. Md. Geol. Survey, Vol. V, pp. 219-636.

satisfactory results. A bituminous coal closely corresponding in composition to the so-called "gas coals" is therefore to be preferred. The amount of sulphur should not exceed 3 per cent., and the nearer it approaches nothing the better. The content of ash should be low, principally because a high content of ash decreases the heating value of the coal, but also because about half of the ash goes into the mixture, and in large amounts this would contaminate and interfere to some extent with the composition of the finished product.

The coals of Maryland occur in the western part of the State in several distinct basins. The principal and most important of these basins is the Georges Creek, in which the well-known Pittsburg Seam is extensively mined. This synclinal area and the less important basins and coal beds of the State are discussed at length in Part IV, Volume V, of the Maryland Geological Survey reports, and for detailed information the reader is referred to that publication.

The Maryland coals on the whole, and particularly the coal mined from the Pittsburg Seam, are of excellent quality; but because of their high fuel ratio (3 to 4) are better suited for steam, domestic and smithing purposes than they are as gas-making coals and as kiln coals in the Portland cement industry.

Portland cement plants in Maryland will probably obtain their steam coals in Maryland and their kiln coals from West Virginia, where the analyses of the Pittsburg and other seams show a higher content of volatile matter and a lower amount of fixed carbon than the same coal seams in Maryland. The average of a large number of analyses of the Pittsburg Seam in Maryland and of the Pittsburg Seam in West Virginia are quoted below. These two average analyses show that the coal from the Pittsburg Seam in Maryland is lower in volatile hydrocarbons and higher in fixed carbon than the coal mined from the same seam in West Virginia. None of the Maryland coals would be considered typical gas coals since a content of as much as 25 per cent. volatile matter is considered a rare occurrence.

The following average analysis of the West Virginia Pittsburg Seam shows a rather high content of sulphur. Coals as low in sulphur as 1 per

cent., however, are to be had, and hence there would be no difficulty in obtaining kiln coal of suitable composition, and at cost at the plant little if any higher than if the coal were mined in Maryland.

AVERAGE ANALYSES OF PITTSBURG COALS FROM MARYLAND AND WEST VIRGINIA.

	Md.*	W. Va.†
Fixed carbon	72.96	53.83
Volatile matter	18.81	37.47
Moisture	.70	1.43
Ash	7.26	7.27
Sulphur	1.01	2.59

* Vol. V, Part IV, p. 633. Md. Geol. Survey.
† Vol. II, p. 205. W. Va. Geol. Survey.

MANUFACTURE OF PORTLAND CEMENT.

The Proportioning of Cement Mixtures.

Newberry, some 10 years ago, proposed a formula for calculating the relative proportions of clay and limestone which should be used in making cement. His formula is based on the assumption that the lime in cement is all combined to form dicalcium aluminate and tricalcium silicate. It was at one time extensively used in proportioning marl and clay and limestone and clay, and in spite of the fact that the assumptions upon which it was based have been recently shown to be wrong it is still used by many chemists for this purpose.

In the formula which Newberry proposed for the constitution of Portland cement, viz., $3CaO \cdot SiO_2 + 2CaO \cdot Al_2O_3$, one part of silica corresponds by weight to five parts of calcium carbonate, and one part of alumina to two parts of calcium carbonate. In the calculation the percentage of iron oxide is added to the percentage of alumina, the total being considered as alumina.

EXAMPLE 1. ANALYSES OF RAW MATERIALS.*

	Limestone.	Shale.
Silica (SiO_2)	7.06	62.20
Alumina (Al_2O_3)	1.08	21.25
Iron oxide (Fe_2O_3)	1.01	5.23
Calcium carbonate ($CaCO_3$)	87.75	.64
Magnesium carbonate ($MgCO_3$)	1.70	.94

* Partial analyses of raw materials used by the Security Cement and Lime Company, Security, Md.

The shale requires, according to the formulas:

Parts of Shale.			Ratio of $CaCO_3$.		$CaCO_3$ required.
Silica (SiO_2)	62.20	×	5	=	311.00
Alumina (Al_2O_3)	21.25	×	2	=	42.50
Iron oxide (Fe_2O_3)	5.23	×	2	=	10.46
					363.96
Calcium carbonate ($CaCO_3$)	0.64				.64
					363.32

Since the limestone itself contains silica, alumina, and iron, part of its lime will be required to satisfy these constituents:

Parts of Limestone.					
Silica (SiO_2)	7.06	×	5	=	35.30
Alumina (Al_2O_3)	1.08	×	2	=	2.16
Iron oxide (Fe_2O_3)	1.01	×	2	=	2.02
					39.48

This subtracted from the total $CaCO_3$ leaves 48.27 parts of $CaCO_3$ in each unit of limestone. As 363.32 parts of $CaCO_3$ are required for each unit of shale the units of limestone required per unit of shale will be:

$$\frac{363.32}{48.27}=7.53$$

In other words, for each ton of shale are required 7.53 tons of limestone.

In actual practice the above calculation is simplified and accelerated by the use of diagrams and tables analogous to those employed in the operation of blast furnaces.

In practice, the full amount of lime called for by Newberry's formula is never employed, the percentage in all cases depending upon the fineness to which the raw materials are ground and the degree of burning. Usually about 90 per cent. of the lime called for by the formula is employed, or the figures 4.5 are used in place of 5 as the factor for the silica, and 1.8 instead of 2 as the factor for the alumina.

Practically all American Portland cements satisfy the formula (Michaelis' "hydraulic modulus"):

$$\frac{\text{per cent. Lime}}{\text{per cent. Silica}+\text{per cent. Iron Oxide}+\text{per cent. Alumina}}=1.9 \text{ to } 2.1$$

Meade states * that in his work he found that where the raw materials were ground to a fineness of 95 per cent. through a No. 100 test sieve, he never failed to make a sound cement of normal setting qualities and good strength when the composition of this cement met the ratio:

$$\frac{\text{per cent. Lime}}{\text{per cent. Silica} + \text{per cent. Iron Oxide} + \text{per cent. Alumina}} = 2.05,$$

provided the ratio between the silica and the alumina was not less than 2.5.

In mill practice, however, it is seldom that as high a ratio as this can be carried. Just what the ratio should be depends upon conditions of manufacture and the nature of the materials. When the alumina is low this ratio is often carried as low as 1.9 without obtaining quick-setting cement. On the other hand, when the alumina is high it is often, but not always, necessary to carry the ratio as high as 2.05 to avoid quick-setting cement.

The formula used to proportion the raw materials so as to give a cement having a ratio of 2.05 is as follows:

$$\frac{\text{Limestone (or Marl)}}{\text{Clay (or Shale)}} = \frac{(\%\ SiO_2 + \%\ Fe_2O_3 + \%\ Al_2O_3 \text{ in Clay}) \times 2\tfrac{1}{4} - (\%\ CaO \text{ in clay})}{(CaO \text{ in limestone}) - (\%SiO_2 + \%Fe_2O_3 + \%Al_2O_3 \text{ in limestone})} \times 2\tfrac{1}{4}.$$

The additional 0.2 added in the formula is to take care of the small amount of coal ash which enters the cement.

In the example given above the proportions of shale and limestone would be as follows:

$$\frac{\text{Limestone}}{\text{Shale}} = \frac{(62.20 + 21.25 + 5.23) \times 2\tfrac{1}{4} - 0.36}{49.14 - (7.06 + 1.08 + 1.01) \times 2\tfrac{1}{4}} = \frac{199.17}{28.58} = 6.98.$$

The formulas used above are very valuable in determining the relative parts by weight of limestone and shale entering into a Portland cement mixture, but after a plant has been put into operation and is running on materials of fairly uniform composition it is customary to "control the mix" according to a fixed lime standard, that is to say if it were found that 41.5 per cent. lime (CaO) in the mixture of raw materials

* Meade, R. K. 7th Int. Congr. of App. Chem.; see Chem. Eng., Vol. X, p. 181.

gave the best results the mixture would be made on this basis. In order to do this, however, the ratio of silica to alumina must, and would in a suitable shale deposit, remain approximately constant.

After it has once been determined what amounts of limestone and shale mixed together give the best results the mixture of raw materials may be calculated and controlled according to the percentage of lime (CaO) in the mixture by the following simple algebraical method: *

Where x = weight of limestone in charge.
y = weight of clay or shale in charge.
a = per cent. of calcium oxide in limestone.
b = per cent. of calcium oxide in the clay.
c = per cent. of calcium oxide in the mixture.

$$\text{Then } c=\frac{ax-by}{x-y} \text{ or } x\,(a-c)=y\,(a-b) \text{ or } \frac{x}{y}=\frac{c-b}{a-c}.$$

The problem of determining the probable composition of a cement from its raw materials is often presented. Its solution is by no means easy. The usual rule is to add together the percentages of silica, oxide of iron and alumina, lime and magnesia, and to divide this sum into the percentage of each compound, multiplied by 100, for the percentage of that compound which will be present in the clinker. If this rule is followed, the results obtained for silica and for iron oxide and alumina will be too low and the lime much too high. This is because the ash of the fuel enters into the composition of the clinker, and also because the clinker contains other constituents present in the raw materials and not entirely volatilized in burning, viz., soda, potash, sulphur trioxide, etc., carbon dioxide and water.

The accurate calculation of the composition of the clinker from an analysis of the raw material is, therefore, impossible, and the best that can be done is to assume certain corrections.† First of these is for the coal ash entering into the clinker. Experiments show that in the rotary kiln about one-half the ash enters the clinker. The West Virginia

* Ohio Geol. Survey, Bull. III, p. 242.

† Meade, R. K. 7th Int. Congr. App. Chem.; see Chem. Eng., Vol. X, p. 181.

gas-slack coal contains about 10 per cent. of ash in practice. This ash is composed of about 40 per cent. silica and about 20 per cent. each of iron oxide and alumina. If, therefore, 90 pounds of coal are required to burn a barrel of cement, about 16 pounds (equivalent to 1.5 pounds of ash) are required per 100 pounds of raw material burned. Assuming half the ash to enter the raw material, the silica in the latter is increased by $\frac{1}{2} \times 1.5 \times 0.40 = 0.30$ per cent., and the iron and alumina each by $\frac{1}{2} \times 1.5 \times 0.20 = 0.15$ per cent.

Analyses of Lehigh Valley clinker when fresh from the kilns show it to contain about 2 per cent. of potash, soda, sulphur compounds, carbon dioxide, and water combined. Clinker from other localities will probably not vary widely from this.

Assuming the above corrections, Meade's rule for calculating clinker from the mix analysis is as follows:

Add together the percentages of silica, alumina, oxide of iron, lime, and magnesia. To the sum add 2.75. Call the result the "Clinker Total."

To find the percentage of silica, add 0.30 to the percentage of silica in the raw material, multiply the sum by 100 and divide by the "Clinker Total" as found above. The result will be the percentage of silica in the clinker.

To find percentage of iron oxide, add 0.15 to percentage of alumina in the mix, multiply by 100 and divide by "Clinker Total," etc.

To find percentage of lime or magnesia, divide percentages of these by "Clinker Total," etc.

EXAMPLE. ANALYSIS OF RAW MATERIAL.

Silica (SiO_2)	13.44	
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	6.54	
Lime (CaO)	41.84	
Magnesia (MgO)	1.93	
		63.75
Correction for ash, etc.		2.75
Clinker Total		66.50

Percentage of Silica:

$$100 \times \frac{13.44 + 0.30}{66.50} = 20.66$$

Percentage of Alumina and Iron Oxide:

$$100 \times \frac{6.54 + 0.30}{66.50} = 10.29$$

Percentage of Lime:

$$\frac{100 \times 41.84}{66.50} = 62.92$$

Percentage of Magnesia:

$$\frac{100 \times 1.93}{66.50} = 2.90$$

Probable composition of Clinker:

Silica (SiO_2)	20.66
Alumina (Al_2O_3)	10.29
Iron Oxide (Fe_2O_3)	
Lime (CaO)	62.92
Magnesia (MgO)	2.90

COST OF PORTLAND CEMENT PLANTS.

The capital required to build a cement plant depends on the cost of the kilns, the machinery installed, and the structures erected both for storage of the finished product and for the purpose of housing the machinery of the plant and the kilns. In short, it depends, as must be obvious, on the capacity and character of the plant.

The building of a cement works, aside from the original cost of the land that carries the necessary raw material, is an expensive undertaking and requires a large outlay of capital. The cost of plants ranges from a single 60-foot kiln plant, representing an expenditure of about $150,000, to plants with five or more 125-foot kilns costing somewhat less per barrel produced, but requiring in the aggregate a capital of $1,000,000 or more.

The authors know, however, of but one plant that has been built and put in operation recently where the cost was in the neighborhood of $100,000. The plant referred to was a single-kiln plant built at Leeds, Alabama, by Major F. H. Lewis, and plans are now on foot to double its capacity. It is probable that a similar plant constructed under present conditions would cost nearer $150,000.

In general it may be said that a Portland cement plant will cost from

$1.00 to $1.50 per barrel of its estimated output. That is, a plant producing 500,000 barrels per annum will cost from $500,000 to $750,000 as a construction charge. With economy of design and with the construction in experienced hands the first figure can be adhered to, but inexperienced engineers and constructors can readily run the cost beyond even the latter figure.

At present the tendency seems to be to start with a 2000- or 3000-barrel-per-day plant, costing from $700,000 to $1,000,000, with the plant so designed that later on other units may be added to the original battery. This arrangement for future expansion entails a larger first cost per barrel of output, but proves a final economy as the capacity of the plant is increased. It is probable that no plants of smaller capacity than 2000 barrels per day could now be operated at a profit in Maryland.

In the early days of cement making 60-foot kilns, 6 feet in diameter, were almost universally used. With the development of the industry has come the introduction of larger and longer kilns, so that now the length of kiln used is from 80 to 250 feet. The length, however, in most of the plants of recent construction ranges between 120 and 130 feet, and the diameter between 7½ and 8 feet.

The relative capacity of kilns of different lengths and diameters is given in the following table:

DAILY CAPACITY OF KILNS OF DIFFERENT LENGTHS.

60 × 6 foot kiln is 200 barrels.
100 × 7 foot kiln is 400 barrels.
120 × 8 foot kiln is 500 barrels.
150 × 9 foot kiln is 750 barrels.

The fuel required to burn a barrel of cement decreases with the length of the kiln, and has been found in actual practice to be about as in the table that follows:

POUNDS OF COAL PER BARREL OF CEMENT (380 POUNDS) IN KILNS OF DIFFERENT SIZES.

60 × 6 foot kiln is 110 pounds.
80 × 6 foot kiln is 100 pounds.
100 × 7 foot kiln is 90 pounds.
150 × 9 foot kiln is 80 pounds.

Thus it may be seen that as the length of the kiln is increased not only is there an increase in the capacity, but also a marked decrease in the per barrel cost of fuel because of the heating of the mixture at the upper end of the kiln before it reaches the intenser temperatures below, all of which is in favor of larger sized kilns. Some of the best authorities on the subject believe the tendency to lengthen the kiln is being overdone, and that kilns of about 100 feet in length, all things considered, give the best results in ordinary work even though in certain cases it may be shown that the cost per barrel is less with the longer kiln. It is evident that on this point there is a wide difference of opinion.

The economy of a kiln is not only dependent on its length but also its diameter. Of two kilns, each 100 feet long, one of which is 6 feet in diameter and the other 7 feet, the former will be found to have the greater economy and the latter the larger output. The longer the kiln the more economical it would be, and on this score a kiln 200 feet long would not be too long, but with such a long kiln mechanical difficulties are met with which so far have more than overbalanced the economy effected. Kilns 250 feet long and 12 feet in diameter are now being installed at a plant on the Hudson River.

Instead of using a long kiln, the Fuller Engineering Company, designers of the plant of the Tidewater Portland Cement Company, at Union Bridge, are installing dryers after the kilns, through which the waste gases from the kilns are passed and utilized in drying the shale and limestone. This system obviates the necessity for kilns longer than 125 feet.

The total cost of manufacture of a barrel of Portland cement varies with the locality. Portland cement made by the dry process ranges in cost per barrel between 50 and 85 cents, while by the wet process, where marls are mixed with muds and clays, the cost is greater owing to the cost of drying the marl, and owing to its wet condition while excavating and transporting it to the mill. The selling price ranges between $1.25 and $1.50 a barrel, depending upon trade conditions, and thus the manufacturer situated near a large market even after paying for trans-

portation and selling costs is usually left a very flattering margin of profit, though not always, as for instance, when the cost of manufacture runs high because of unusual local conditions. This, unfortunately, sometimes happens as the result of insufficient care having been taken in the selection of the raw materials, the design of the plant, the location of plant, with reference to transportation, fuel supply, and market, and a neglect to arrange the question of rates with the transportation companies upon whom the plant is dependent for assembling the materials entering into the manufacture and for marketing of the finished product.

OTHER CEMENTS.

Before leaving the discussion of cements it seems advisable to add a brief discussion of several other cements not made from limestone, such as slag and oxychloride cements.

SLAG OR PUZZOLAN CEMENTS.

Slag or puzzolan cements are made from blast-furnace slag or natural puzzolan. The former should contain from 22 to 30 per cent. of silica; 11 to 16 per cent. alumina and iron oxide; 49 to 52 per cent. of lime; less than 4 per cent. magnesia; 1.5 per cent. alkalies, and show less than 2.5 to 7.5 per cent. loss by ignition. The puzzolan or volcanic tuffs usually run higher in silica, about the same in alumina, very much lower in lime, but with from 5 to 9 per cent. in alkalies which are practically lacking in slags.

Slag is locally abundant as the chief waste product of blast furnaces where its utilization would be appreciated. Since for cement purposes the slag must be of uniform composition, and since such uniformity cannot be maintained when different ores are used without endangering the uniformity of the pig iron produced, the blast-furnace operators who use more than one kind of ore prefer to leave the slag unutilized rather than lower the standard quality of their iron.

Slag cements are usually more porous and less resistant to disintegration and abrasion than Portland cements, though generally serving well for marine work. From these and other cognate reasons little slag

cement is produced in America, the only plant making it in Maryland suspending operations several years ago.

OXYCHLORIDE CEMENTS.

Oxychloride cements are of less commercial importance than any of the other complex cements. They differ from the latter in that they are entirely free from silica, and their setting properties are due to the formation of hydroxychlorides.

The oxychloride cements are made by treating magnesia (MgO) with a solution of magnesium chloride ($MgCl_2$) of 25° to 30° Baumé. A paste is thus formed which sets tolerably rapidly and results in a hard, white mass that possesses unusual compressive strength and a tensile strength exceeding that of Portland cement. They are poor conductors of heat, easily molded and satisfactory for certain kinds of refined dental and interior work, but their permanence, compared with that of other cements, is still a matter of discussion.

SUMMARY AND STATISTICS OF LIME AND CEMENT INDUSTRIES.

The industries based upon the utilization of limestones are important and are constantly increasing in their gross production. These may be grouped according to the form in which the product reaches the market and the uses to which they are put by the consumer. *Limestone,* as such, is used rough or dressed for building purposes, paving, riprap, etc.; crushed for road-making, railroad ballast, and concrete; and in various forms for metallurgical and chemical purposes. The extent of the trade in limestone, exclusive of marble, may be seen from the following table indicating the value of the annual production in the United States:

VALUE OF THE ANNUAL PRODUCTION OF LIME AND LIMESTONE, EXCEPTING MARBLE, IN THE UNITED STATES.

	Building.	Flagging, curbing, paving.	Rubble, Riprap.	Crushed.	Flux.	Sugar.	Misc.	Lime burned.	Total.
1900	$4,330,706	....	$582,488	$3,953,469	$3,687,894	......	$629,900	$6,797,496	$20,181,453
1901	5,219,310	$468,925	1,024,109	5,271,642	4,569,836	......	1,171,045	8,204,054	26,014,921
1902	5,563,084	578,652	1,644,886	7,452,780	5,271,252	......	492,384	9,335,618	29,993,610
1903	4,981,241	1,037,888	1,214,540	8,580,866	5,423,732	......	422,826	9,255,882	31,216,972
1904	4,543,760	574,945	1,860,732	9,558,626	4,702,768	[$613,649]	324,484	9,951,456	31,516,771
1905	5,312,183	643,012	1,518,898	10,487,638	7,004,265	[408,548]	650,666	10,941,680	36,558,342
1906	5,093,631	930,422	1,474,660	11,073,265	7,612,692	822,330	315,042	12,480,653	39,807,795
1907	4,580,226	1,008,229	1,687,773	13,675,453	9,144,489	316,860	1,824,601	12,656,705	44,894,336
1908	4,566,522	593,297	2,254,882	12,908,207	5,905,241	361,186	1,092,667	11,091,186	38,773,188

The figures show a very stable industry in which the total annual production has increased slowly but steadily in sympathy with the general increase in population and wealth in the United States. The most noticeable features of the industry supplying stone for special uses are the steady and relatively rapid growth in the output of stone for flux and the crushed stone used in road, railroad, and concrete work.

The burning of limestone to lime is likewise an industry increasing rather steadily with the growth of the country. The uses to which the burnt lime is put are for building, agricultural, and chemical purposes. The accompanying table gives the value of the annual production in the United States since 1896:

VALUE OF THE ANNUAL PRODUCTION OF LIME IN THE UNITED STATES, 1896-1908.

1896	$6,327,900
1897	6,390,487
1898	6,886,549
1899	6,983,067
1900	6,797,496
1901	8,204,054
1902	9,335,618
1903	9,255,882
1904	9,951,456
1905	10,941,680
1906	12,480,653
1907	12,640,512
1908	11,091,186

The industries based upon the use of limestone in the manufacture of cements are of special importance and interest both because of the remarkable growth of the Portland cement industry and the accompanying decline in the production of natural cement.

The following table, based upon the estimates of early production by Cummings * and the recent statistics gathered by the U. S. Geological Survey, is a comparative statement of the production in the gross quantities produced annually:

* Cummings, American Cements, 1898, p. 298.

	Natural Bbls.	Portland Bbls.	Puzzolan Bbls.
1818-1830	300,000	....	....
1830-1840	1,000,000	....	....
1840-1850	4,250,000	....	....
1850-1860	11,000,000	....	....
1860-1870	16,420,000	....	....
1870-1880	22,000,000	82,000	....
1880-1890	43,589,067	1,477,000	....
1890	7,082,204	335,500	....
1891	7,451,535	454,813	....
1892	8,211,181	547,440	....
1893	7,411,815	590,652	....
1894	7,563,488	798,757	....
1895	7,741,077	990,324	....
1896	7,970,450	1,543,023	12,265
1897	8,311,688	2,677,775	48,329
1898	8,418,924	3,692,284	150,895
1899	9,868,179	5,652,266	335,000
1900	8,383,519	8,482,020	365,611
1901	7,084,823	12,711,225	272,689
1902	8,044,305	17,711,225	478,555
1903	7,030,271	22,342,973	525,896
1904	4,866,331	26,505,881	303,045
1905	4,473,049	35,246,812	382,447
1906	4,055,797	46,463,424	481,224
1907	2,887,750	48,785,390	557,252
1908	1,686,682	51,072,012	151,451
	227,102,085	395,567,395	4,145,657
			626,815,137

From the foregoing table it may be rapidly seen that of the three hydraulic cements Portland cement is easily chief. The figures also display the wonderful growth in this industry during the present generation. In 1880 the total output of Portland cement was only 42,000 barrels, less than one one-thousandth of the present annual production, and only 1.8 per cent. of the cement now consumed each year. At the same time natural cement was produced to the extent of 2,030,000 barrels. In the meantime the production has increased to a maximum annual production of 9,868,179 barrels in 1899, only to decline during the last decade to a production below that of 1880.

Puzzolan or slag cement has never been produced extensively in this country, the annual production scarcely exceeding 1 per cent. of the Portland cement manufactured during corresponding years.

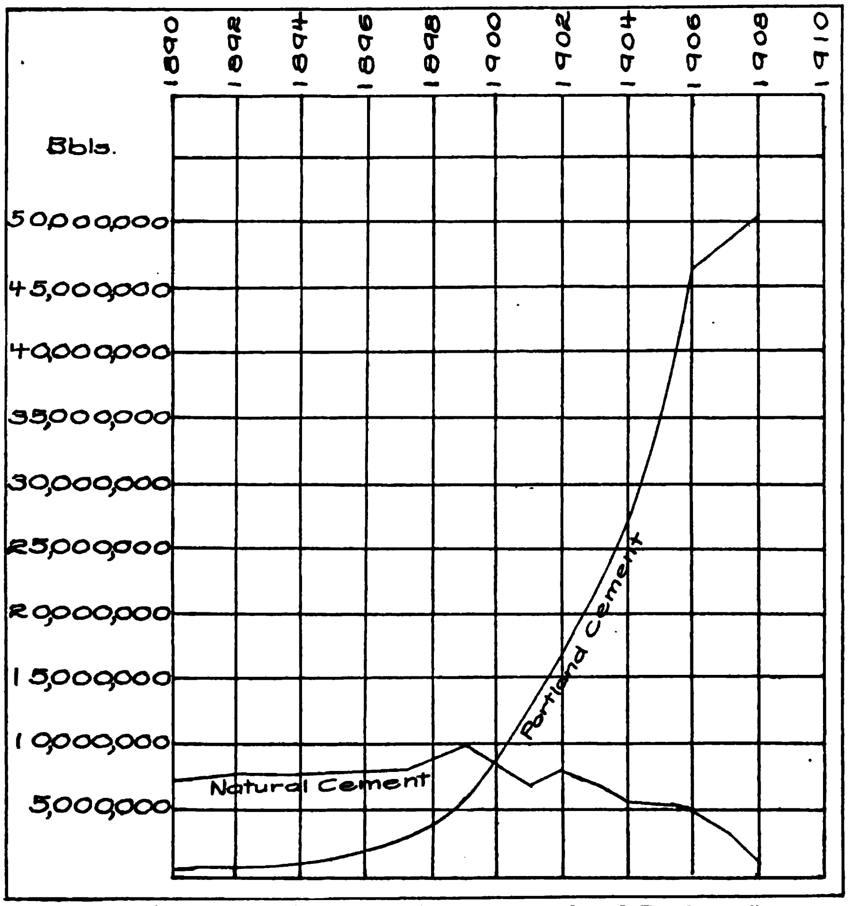


FIG. 19.—Diagram showing production of Natural and Portland Cements, 1890-1908.

The annual production of each variety for the year 1908, with its value and price per barrel, is as follows:

	Quantity.	Value.	Price per bbl.	Rela price.
Portland	51,072,612	$43,547,679	$ .85	$1.00
Natural	1,686,682	834,509	.44	.73
Puzzolan	151,451	95,468	.63	.74
	52,910,925	$44,477,653		

The price per barrel is the average price f. o. b. at the mill. Since natural cement barrels contain only 265 pounds as against 380 pounds in barrels of puzzolan and Portland cements, their relative prices per pound are more favorable to natural cement than appears. Puzzolan and natural cements cost between 70 and 75 per cent. of Portland, weight for weight.

The phenomenal growth of the Portland cement industry is shown in the following figures, which show the annual production of natural, Portland, and puzzolan cements and pig iron.

PRODUCTION IN SHORT TONS OF CEMENT AND PIG IRON.

	Natural.	Portland.	Puzzolan.	Pig Iron.
1890	938,392	67,100	.....	10,307,073
1891	987,328	91,000	.....	9,269,454
1892	1,087,976	101,500	.....	10,255,840
1893	982,065	114,100	.....	7,979,442
1894	1,002,162	159,700	.....	7,456,274
1895	1,025,693	199,700	.....	10,579,864
1896	1,056,085	308,600	2,530	9,657,902
1897	1,101,299	535,500	9,183	10,811,001
1898	1,115,494	716,900	28,670	13,186,806
1899	1,307,584	1,161,100	63,650	15,255,187
1900	1,110,816	1,696,400	69,466	15,443,951
1901	938,639	2,542,200	51,811	17,783,756
1902	1,065,880	3,446,100	90,925	19,959,863
1903	931,511	4,458,600	99,920	20,170,362
1904	640,764	5,601,200	57,579	18,476,676
1905	592,679	6,665,304	72,665	25,751,465
1906	537,394	8,828,050	78,132	28,344,053
1907	362,545	9,269,224	105,928	28,875,124
1908	223,485	9,703,896	28,776	17,848,340

LIME AND CEMENT MATERIALS IN MARYLAND.

Introductory.

THE GEOGRAPHY OF THE STATE.

The State of Maryland is divided into three physiographic provinces, known as the Coastal Plain, the Piedmont Plateau, and the Appalachian Region. The Piedmont Plateau lies between the Appalachian Region on the west and the Coastal Plain on the east. The Appalachian Region

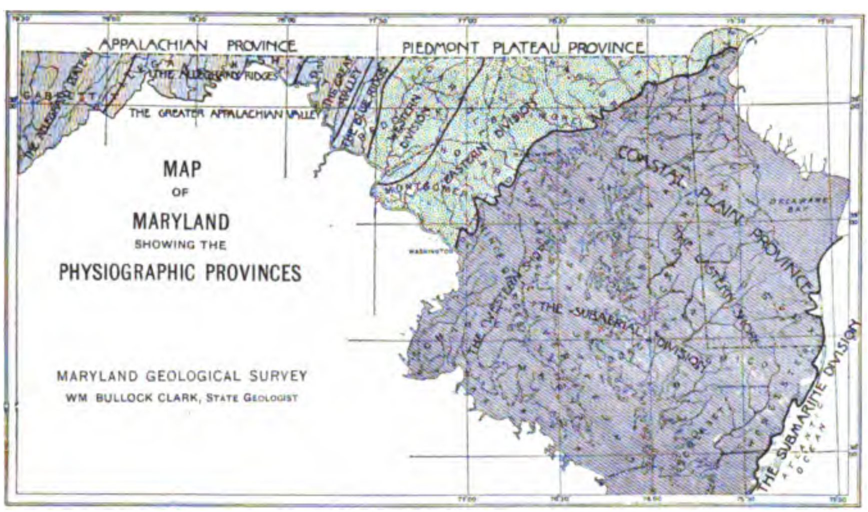


Fig. 20.—Map of Maryland showing the Physiographic Provinces.

includes all that part of the State west of North Mountain, and is subdivided into the region of the Alleghany Ridges and into a more western region, the Alleghany Plateau. The Coastal Plain lies east of the sinuous line shown on the accompanying map. This line passes across the State in a northeasterly direction through Washington and Baltimore and the mouth of the Susquehanna. The Coastal Plain is divided into aerial and subaerial portions. The Piedmont is also divided. That part of the Plateau province east of the Blue Ridge, which is the Piedmont

proper, is separated into an eastern and western division by Parr's Ridge, while the area west of the Blue Ridge is referred to as the Great Valley Region.

THE GEOLOGY OF THE LIME AND CEMENT MATERIALS.

Each of the physiographic provinces briefly described above differs both in the matter of topography and geology. There is a gradual rise in elevation from the low-lying Coastal Plain of the east to the mountainous Appalachian Region of the west. Going from the eastern part of the State to its western boundary the traveler, besides reaching higher and higher altitudes, crosses first the younger deposits of the Coastal Plain, then the ancient rocks of the Piedmont, and finally traverses strata that, geologically speaking, become progressively younger.

The youngest formations of the State are confined to the Coastal Plain, where they consist of clays and other more or less poorly consolidated sediments. As a result of the absence of hard and resistent rocks in this section of the State it is low and flat, and but for its terraces is relatively featureless as regards topography. In this respect it is unlike the Piedmont Plateau, where the topography is rolling and undulating and the rocks are both harder and older and different in character from those of the adjoining Coastal Plain. The rocks of the western and mountainous part of the State are, on the other hand, younger in age than those of the Piedmont, but are much older than most of the rocks of the Coastal Plain. Moreover, considered as a whole, they are quite different in a great many respects from the characteristic rocks of the two provinces first referred to above.

Argillaceous and calcareous materials occur in all three of the regions that have been discussed. In the eastern Piedmont the limestones are best developed in the vicinity of Texas and Cockeysville, while suitable argillaceous material occurs near at hand in the Coastal Plain. The Mesozoic and Cenozoic rocks of the latter physiographic division also carry marls which, as the result of exploitation work, may prove to be a source of cement material. Furthermore, the regions of the Piedmont and Coastal Plain are traversed by numerous railroads. These, together

with convenient and cheap water transportation, afford a means of assembling the raw materials and likewise the facilities for carrying the finished products to local and distant markets.

Suitable materials for making lime and cement occur in the western Piedmont section, but not so abundantly as farther west. Some of the limestones of this section which occur along the line of the Western Maryland Railroad, especially those deposits near Union Bridge, are extremely pure and are found in sufficient quantity to form the basis of a small but thriving industry. They are about to be used in conjunction with the associated volcanic slates and the nearby Triassic shales to form the basis for the manufacture of Portland cement. A plant located in this region would have to depend entirely on the one railroad, the Western Maryland, now known also as the Wabash, for transportation. It would have the advantage, however, of being within 50 miles of Baltimore and near Washington, also, both large markets for Portland cement.

Limestone of known Cambro-Ordovician age occurs on both sides of the Blue Ridge. East of the Blue Ridge this limestone is of great thickness and of wide distribution, and contains beds of varying degrees of purity; it occurs in the vicinity of Frederick and forms what is known as the Frederick Valley. From Frederick northward it is traversed by the Northern Central Railway of the Pennsylvania system, and southwest and eastward by the Baltimore and Ohio Railroad. Both lines center at Frederick and furnish transportation facilities for assembling (depending on which is desired) either the shales of volcanic and undetermined origin on the east side of the valley, or the Triassic shales on the west at some fixed point for manufacture within the limestone belt, and along one or the other of the routes mentioned.

The largest areal distribution of limestone in the State is in the Hagerstown Valley. Shale also occurs in abundant quantity and deposits of suitable quality for the manufacture of Portland cement may usually be found without very great difficulty. The valley is traversed by five different railroad lines that center and radiate from Hagerstown. By reason of the transportation facilities and the abundance of raw materials this valley region is probably the most promising field for the investiga-

tion and successful location of cement materials in Maryland. The only Portland cement plant now in operation in the State is located within this section, near Hagerstown, and unless this plant is followed in the near future by the building of one or two others it will be most surprising.

The limestones of the mountainous section of Maryland are neither so thick nor so accessible for working as the beds of the Shenandoah group of limestones that form the floor of the Hagerstown and Frederick valleys. These mountain limestones, namely, the Cayuga, Helderberg, and Greenbrier, are much higher up in the geological column than the limestone beds of the Hagerstown Valley. The Western Maryland or Wabash Railroad cuts across the strike of these mountain limestones at a number of points in the western part of Washington County and between Hancock and Cumberland. Several railroads center at Cumberland, and a number of very promising points for the location of plants for the manufacture either of lime or cement are known to occur. These are discussed in detail on a later page.

USES, VALUE, AND DISTRIBUTION BY DISTRICTS.

The limestones of Maryland which are largely used in structural work and for building purposes, and as the basis of both its lime and natural cement industries, and are likewise equally necessary in the manufacture of Portland cement, occur in workable quantities in 7 of the 23 counties of the State, and if Harford is included outcrop in 8.

The limestones of Harford, Baltimore, Howard, and Carroll, and those also of Frederick, with the exception of the group of Shenandoah limestones, occupying the Frederick and Glade valleys, will be discussed under the head of Piedmont limestones. The Shenandoah limestone of Frederick will be discussed later under the head of Frederick Valley limestones, and the limestones of the same age occurring in Washington County under the caption Hagerstown Valley. Finally, the limestones of the western part of Washington County which were laid down at a later geological time than the Shenandoah will be considered along with

the limestones of Allegany and Garrett counties, in reference to their chief occurrence in the Appalachian division.

PIEDMONT PLATEAU.

Piedmont Plateau is the name used for the physiographic division of the State that extends from the Coastal Plain on the east to the Catoctin or Blue Ridge mountains on the west. Excepting the Triassic area and the Shenandoah limestones east of the Blue Ridge the characteristic rocks of the region are extrusive and intrusive igneous rocks, both altered and unaltered, together with more or less metamorphosed representatives of limestones, shales, and sandstones. These rocks give this region its characteristic undulating, and in certain sections noticeably hilly, topography. The hard quartzites and rocks of igneous origin, but chiefly the former, are the main ridge-makers and form the ridges on one side of the valleys occupied by limestones, while hills or ridges composed of schists may rise to lower altitudes on the other.

For the convenience of discussion the Piedmont section is divided into an eastern and a western section. Within the former occur the limestones and schists and quartzites of Harford, Baltimore, and Howard counties. The limestones and marbles of this region lie to the east of the northeast-southwest boundary line separating the counties of Baltimore and Carroll. Between this boundary and a line on the west passing through Frederick Junction, having the direction N 30° – 35° E, are found the crystalline limestones, shales, slates, schists, quartzites and altered volcanic of the western division of the Piedmont. The limestones of this western division are confined to two counties, Carroll and Frederick.

The accompanying map, Figure 20, showing the physiographic provinces of the State takes Parrs Ridge as the dividing line between the eastern and western Piedmont divisions. This is the most natural line of division between the two sections, for Parrs Ridge extends in a northeasterly direction from the Potomac entirely across the State into Pennsylvania. It is the most prominent topographic feature of the central Piedmont, and acts as a watershed which separates the Piedmont

into two distinct drainage areas. However, as certain of the limestones characteristic of the western division of the Piedmont are exposed northeast of Westminster, it has been thought best to take for the present discussion a dividing line which follows in its northeastern part the boundary between Baltimore and Carroll counties.

EASTERN DIVISION OF THE PIEDMONT.

The limestones of the eastern division of the Piedmont are well developed in Baltimore County, but occur sparingly and are of little economic importance in both Harford and Howard. They apparently underlie the Wissahickon schists and are superjacent to the Setters quartzites. Their exposure in and occupancy of the larger and more fertile valleys, particularly the valleys of Baltimore County, is the result of structural relationships, and is due also to the fact that limestones are unable to withstand, like schists and quartzites, the erosive agents of nature.

Geology.

GEOLOGICAL STRUCTURE.—The structure and trend of the rocks of this section are strikingly similar to the structure and trend as exhibited in the Appalachians.* Their minor folding, showing synclines succeeding anticlines and small overturns and faults, has, in a measure, furnished the key that has led to the present understanding and interpretation of the major structure of the region. This, however, involving as it does an earlier deformation, probably Taconic in age, is far more complicated and has been worked out with much more difficulty than the much simpler and more apparent stratigraphic relationships seen within the region of the Appalachians. The forces that were exerted at the close of the Paleozoic resulted in the complicated folding of the rocks of the eastern and western Piedmont and in the more open folding of the Appalachians. This is seen in the parallel trend of their rocks and the concentric arrangement of the formations of the three regions about a common center situated near Baltimore.

* Mathews, E. B. Geol. Soc. Amer. Bull., Vol. 16, p. 342.

FIG. 1.—BEAVER DAM QUARRY, COCKEYSVILLE.

FIG. 2.—WEST END OF DITMAN QUARRY, TEXAS.

VIEWS OF EASTERN PIEDMONT QUARRIES.

The limestones and associated metamorphosed sedimentary rocks of the eastern Piedmont have a general northeasterly strike and trend, which bends around still further to the east as the rocks are followed from the southern exposures in Harford through Baltimore and Howard counties. Situated near the center of the radiating movements whose action in a southeasterly to northwesterly direction brought about the deformation, elevation, and deflection eastward of the Appalachian strata, the rocks of the eastern Piedmont have in consequence been subjected to forces of the most complex nature.

The formations of this region are folded into synclines and anticlines, here and there partially overturned, and in places faulted and cut by igneous intrusions; but the most unusual feature is the torsional folds which have recently been described by the senior author.*

GEOLOGICAL AGE.—The limestone of Baltimore County has been correlated with the Shenandoah limestone and its age is therefore thought to be Cambro-Ordovician. Fossil forms by which its age might be more accurately determined have never been found. They are probably entirely absent, having been destroyed by strong metamorphic action. The heat and pressure concomitant with the metamorphism to which this limestone has been subjected not only has removed, so far as known, all trace of fossil remains, but has also completely changed the original character of the rocks. Once a limestone composed for the most part of amorphous calcium carbonate, it is now a highly crystalline marble largely composed of grains of calcite and dolomite. Physically, it varies in texture from being loose granular to fine-grained, compact, and highly cemented crystalline limestone or marble. At the typical occurrence at Cockeysville, in Baltimore County, it occurs in the latter form, and has hence been given the name Cockeysville marble.

This crystalline limestone or Cockeysville marble has, as mentioned above, been correlated with the Shenandoah limestone. Nevertheless for the reasons that have been stated its exact position in the stratigraphic column has never been definitely determined. The fact, how-

* Johns Hopkins Univ. Cir., 1907.

ever, that on either end of the extension of the Cockeysville marble and the underlying and superjacent formations there is a sequence into sedimentary rocks of known horizon affords a correlation such as given, but one which, no matter how striking and convincing it may be, until further data are adduced, can be only tentative and unsatisfactory.

However, for use in economic work the age of this crystalline limestone is not nearly as important as its actual occurrence, its quality, thickness, and its availability for use in making limes and cements. It varies in thickness from 0 feet to 2300 feet, and has an average thickness that has been estimated to be a little over 1100 feet. The quality of the stone is another variable quantity. It ranges from an almost pure coarse-grained calcium carbonate to one high in magnesium carbonate and finer in grain. It may also contain at the same time different amounts of other impurities. It is worked principally in the vicinity of Texas and Cockeysville. It has also been quarried for building purposes or to burn into lime elsewhere in Baltimore County, but compared with the operations of the Texas-Cockeysville district these have been unimportant and comparatively insignificant.

Distribution of Lime and Cement Materials in the Eastern Piedmont.

CALCAREOUS MATERIALS.—The establishment of a Portland cement industry in the eastern Piedmont requires satisfactory argillaceous and calcareous raw materials. The lime-burning industry, however, requires only the latter. The available argillaceous materials consist of residual clays and schists and clays of the Mesozoic and Cenozoic formations which occur nearby within the region of the Coastal Plain. The calcareous materials are limited to the Piedmont.

The most valuable deposits for lime and cement in the eastern Piedmont are found on either side of the main line of the Northern Central Railroad between Sherwood and Cockeysville, and along the Maryland and Pennsylvania Railroad between Lock Raven and Glen Arm. The most extensive operation at present is in the northern portion of the former area in the vicinity of Texas and Cockeysville.

Cockeysville and Texas District.—At Texas the stone is quarried chiefly to burn into lime and to a smaller extent for use for fluxing and building purposes. On the other hand, the more compact, close-grained stone around Cockeysville is taken out chiefly for building purposes. Some of it, however, is also channeled especially for monumental and statuary work, while a small tonnage of the product goes to the neighboring kilns and is there burned into lime.

The limestones of Baltimore County are represented by five distinct types of stone known to the quarrymen by the following names:

1. Alum stone.
2. Blue stone.
3. Dolomite.
4. Magnesian stone.
5. Mica-banded limestone.

Each has its characteristic mineralogical and chemical content and distinctive physical appearance; and, moreover, each differs more or less in the uses to which it is best adapted and the purposes for which it is generally employed.

The *alum stone* is a coarsely crystalline limestone which occurs typically exposed in the Ditman quarry west of Texas. It is composed of large and small grains of calcite averaging about $\frac{1}{8}$ of an inch in diameter. These are rather poorly cemented together. It is thus a very loose-textured crystalline limestone, and hence a sample the size of ordinary hand specimens may be shattered easily and separated into individual grains by one or two sharp blows from a hammer. The color is pure white and the stone is called "alum stone" in reference to its supposed resemblance after calcination to large lumps of alum. In composition it is usually extremely pure, as may be seen from the analyses (Nos. 10-11) below. It is less contaminated by impurities, and the presence of accessory minerals than any of the other varieties of limestone occurring in the eastern Piedmont. The accessory minerals most noticeable megascopically are occasional small crystals of pyrites and chalcopyrite. Because of its high content of calcium oxide and loose-textured character

the alum stone is more suitable for manufacture into lime than it is as a building stone or as a road metal, and is accordingly extensively used for the former purpose. In view of its low content of silica and alumina it has also proved acceptable as a fluxing stone either for the open-hearth or blast furnace, and because of its low content of magnesia would be equally well adapted to the manufacture of Portland cement.

ANALYSES OF COCKEYSVILLE LIMESTONE, DITMAN QUARRY, TEXAS.

	No. 10.	No. 11.	No. 13.
Silica (SiO_2)	.36	2.10	4.90
Alumina (Al_2O_3)	.20	.61	1.11
Lime (CaO)	52.72	53.70	50.92
Magnesia (MgO)	.19	.61	1.34
Carbon dioxide (CO_2)	43.77	42.54	41.03
Total	100.24	99.56	99.30

No. 10. Typical specimen of alum stone, Ditman Quarry.
No. 11. Represents 50-foot face of alum stone, Ditman Quarry.
No. 13. Typical specimen of "blue stone," north side Ditman Quarry.

The sample on which the second analysis (No. 11), the bulk sample, was made was taken near the center of Ditman's Quarry and in a direction S. 75° W. from the main battery of kilns, and represents 50 feet of stone or the entire face at this point of the quarry. The alum stone is here flanked on either side by two different types of stone. On the north the so-called "blue stone" is quarried, and on the south the magnesian variety. All three varieties are burned for lime and each yields a different grade, the best lime being produced from the alum stone. The "blue stone" produces a high-calcium lime, while the magnesian stone yields a lime high in magnesia.

All three varieties of stone exposed in the Ditman Quarry have a general westward dip of 15° to 18°. The limestone is fissured throughout the exposure, and especially at the north end of the quarry. Here the fissures dip steeply to the east, the exact angle being close to 85°, and strike N. 70° W.

The "*blue stone*" is a hard, compact crystalline limestone of a prevailing grayish-blue color. Bands of varying width of grayish-blue color

alternate with bands which range in color through light gray to dove and almost white. Like the alum stone it is composed of grains of calcite whose glistening faces make the crystalline character of the rock evident at a glance. These are tightly cemented together so that the rock may be used either as a building stone or burnt into lime. It contains more silica, alumina, and iron than the "alum stone," but nevertheless burns into an excellent grade of lime. It is also low enough in magnesia for manufacture into Portland cement.

The quantity of blue and alum stone in the quarry appears to be ample to furnish the necessary calcareous material for a Portland cement plant of 1500 to 2000 barrels daily capacity for period of at least 25 years, but in order to determine this definitely further and more detailed investigation would be necessary. Analysis No. 13 gives the composition of the blue stone.

The *dolomites* and dolomitic limestones, when the impurities of silica, alumina, and iron are low or are practically absent, are white and hard, and are further characterized by their close-grained texture. They may be seen typically exposed in the marble quarries at Cockeysville where the samples represented by the following analyses were collected:

ANALYSES OF DOLOMITE, BEAVER DAM QUARRY, COCKEYSVILLE.*

	No. 3.	No. 4.
Silica (SiO_2)	0.44	5.57
Alumina (Al_2O_3)	1.22	.40
Iron oxide (Fe_2O_3)	Trace	
Lime (CaO)	30.73	29.08
Magnesia (MgO)	20.87	20.30
Ignition (CO_2, etc.)	47.07	44.26
Total	100.33	99.61

* U. S. Geol. Survey, Bull. No. 150, p. 301.

It may be observed from the above analyses that the argillaceous substances are low while the content of magnesia is high. Burning such a stone would yield a lime too high in magnesia for the average commercial use. The stone is well adapted for building purposes, however,

and is extensively quarried by the chief operator at Cockeysville, the Beaver Dam Marble Company, the product going almost entirely to meet the demands of the building trade.

The extent to which accessory minerals, such as phlogopite, tremolite, biotite, and pyrite occur in the Cockeysville stone is the result not only of the metamorphism which has converted these limestones and dolomites into marble, but is due likewise to the presence in the stone of impurities like silica, alumina, iron, etc. The abundance and variety of accessory minerals depend obviously on the composition of the rock just as much as they do on the heat and pressure to which it has been subjected. The content of accessory minerals in which iron occurs as an essential constituent should be quite low in a marble or limestone that is to be used in exterior structural work. If this is not the case the stone becomes streaked on oxidation of the iron with stains that detract materially from its general appearance.

The above analyses of the Cockeysville marble indicate that the amount of accessory minerals that would be formed would be more or less insignificant because of the small percentage of the necessary elements. Those that do occur principally are tremolite, diopside, and minute and microscopic crystals of phlogopite. In the selected rocks, however, classified here as dolomites, with especial reference to the typical pure white Cockeysville marble, the impurity minerals mentioned form such a small fraction of a per cent. of the whole that they may be considered as occurring in purely negligible quantities in the stone placed on the market.

The term *magnesian stone* is applied to the variety of Cockeysville limestone containing phlogopite, biotite, and other accessory minerals formed from the argillaceous elements silica, alumina, and ferric oxide, as the result of metamorphism. These glistening flakes of yellow and black mica that are rather evenly distributed through the rock, give it a characteristic appearance by which it may always be easily identified.

The following analysis was made on a sample of this stone in which phlogopite was the dominant accessory mineral taken as representative

FIG. 1.—"ALUM STONE," DITMAN QUARRY, TEXAS.
WHITE CRYSTALLINE MARBLE COMPOSED OF LARGE CRYSTALS OF CALCITE.

FIG. 2.—BANDED MAGNESIAN STONE, DITMAN QUARRY, TEXAS.
SHOWING WHITE CRYSTALLINE STONE CROSSED BY BAND IMPREGNATED WITH BROWN MICA.

TYPICAL LIMESTONES OF EASTERN PIEDMONT.

of the crystalline limestone quarried at the south end of Ditman Quarry at Texas:

ANALYSIS (No. 12) OF MAGNESIAN STONE, DITMAN QUARRY, TEXAS.

Silica (SiO_2)	6.65
Alumina (Al_2O_3) } Iron Oxide (Fe_2O_3) }	2.08
Lime (CaO)	33.58
Magnesia (MgO)	15.34
Ignition	41.32
	98.97

This stone when calcined necessarily yields a quick-setting high-magnesian lime. The value of the lime, however, is diminished by its content of mica. The heat of the kiln has very little effect on this mineral, and hence after calcination it is found in the lime in even greater amount than it was in the original rock.

This variety of limestone, known as *mica-banded rock,* has been so called because of the arrangement of the impurities in parallel bands. Of these mineral impurities mica is the most noticeable. This variety of stone varies widely in chemical composition, and having been extremely metamorphosed contains a varied assortment of minerals such as biotite, phlogopite, iron pyrites, quartz, calcite, dolomite, and so on. Bands impregnated with dark-colored minerals alternate with others that are white in color and more or less free from the minerals into which the clayey elements enter as essential constituents.

These white bands, ranging in width from a fraction of an inch to several inches, are composed for the most part of grains of calcite and dolomite. Both sets of bands, the dark-colored and the white, generally lie parallel to what is believed to be the original bedding.

Other Districts.—In other areas, such as the Mine Bank, Dulaney, Caves, Worthington, and Green Spring valleys, this limestone has been quarried in the past and is being worked in a small way now, but principally for local building purposes and for manufacture into agricultural lime. These limestone valleys are either anticlinal in character as in "The Caves," or else the limestone occupies valleys occurring on the

flanks of large anticlines with the limestone forming the valley floor, and are flanked on one side as in the case of the Green Spring Valley, by a quartzite ridge, and on the other with hills of Wissahickon schists.

ARGILLACEOUS MATERIALS.—The clayey materials of the eastern Piedmont consist of residual and transported clays and the Wissahickon schist, while the clays of certain of the Mesozoic and Cenozoic formations of the Coastal Plain are also available for use in combination with the eastern Piedmont limestone. These may be considered in the order mentioned, and each briefly discussed with reference to its value in the manufacture of Portland cement.

Residual and Transported Clays.—Residual clays are found throughout the eastern Piedmont, having resulted from the weathering of the underlying rocks. The different deposits may vary widely both in form, size, and chemical composition. The transported clays which are found in this same region occur in the valleys mixed with the residual soil, and along and in the courses of streams. They also vary in the shape and size of the deposit, but on the whole are finer grained, more homogeneous in character, and more uniform in chemical composition. Careful investigation of these materials on the part of those interested in the location of Portland cement plants would doubtless lead to the location of suitable deposits of clays of both kinds.

Wissahickon Schist.—The Wissahickon schist is an argillaceous to siliceous sedimentary formation that was formerly a shale, but has since been altered by metamorphism to a schist. It is characterized by its high content of such metamorphic minerals as garnet, mica, etc. This formation has been described by Mathews and Miller as consisting of "a series of highly micaceous, very schistose, and often crinkled aggregates of quartz, more or less chloritized biotite and garnet, with accessory orthoclase, cyanite, staurolite, etc." Both its variations in physical character and chemical composition and the stability of its mineral constituents probably make it entirely unsuitable for use in the manufacture of Portland cement.

Mesozoic and Cenozoic Clays.—The most important clayey deposits accessible to the eastern Piedmont district that may be used in the

manufacture of Portland cement in combination with the limestone occurring in the eastern Piedmont lie within the limits of the Coastal Plain. They range in geological age from early Mesozoic to late Quaternary. The formations in which they occur consist of more or less unconsolidated clayey, siliceous, and calcareous sediments that are further characterized by occasional indurated beds.

In numerous instances the Mesozoic and Cenozoic clays, which have been extensively used in manufacture of brick, terra cotta, and other clay products, are found to occur where they may be easily and cheaply won, with the advantage also of being well located for transportation either by water or by rail, and within a comparatively short haul from the deposits of limestone.

The following table gives the order of succession of the formations of Mesozoic and Cenozoic age that occur in Maryland:

TABLE OF COASTAL PLAIN FORMATION.

Cenozoic.		
Pleistocene	Talbot	Columbia Group.
	Wicomico	
	Sunderland	
Pliocene (?)	Lafayette.	
Miocene	St. Mary's.	
	Choptank.	
	Calvert.	
Eocene	Nanjemoy	Pamunky Group.
	Aquia	
Mesozoic.		
Upper Cretaceous	Rancocas.	
	Monmouth.	
	Matawan.	
	Magothy.	
	Raritan.	
Lower Cretaceous	Patapsco	Potomac Group.
	Arundel	
	Patuxent	
Triassic	Newark.	

All of these formations, except the Newark, which occurs in Montgomery, Frederick, and Carroll counties, are confined to the Coastal Plain and its borders. They are limited on the west by the Piedmont, where

they rest unconformably on rocks much older and of very different character. From the Piedmont they dip gently southeastward toward Chesapeake Bay at the rate of 30 to 50 feet to the mile. It is evident from this, therefore, that the younger formations exhibit their greatest areal distribution along and near the bay shore, while going westward up the estuaries of the bay and the streams that flow into it from the "Western Shore" older and older formations are successively crossed until one encounters finally the more ancient rocks of the Piedmont. These relationships are brought out on the geological map of the State recently issued by the Maryland Geological Survey. With this map one may locate also the limestones of the eastern Piedmont and observe the proximity of these to the different formations of the Coastal Plain.

In selecting the materials for a Portland cement plant in the eastern Piedmont the matter of their proximity of occurrence would be one of the first questions to be considered. The plant would necessarily be located at or near the quarry supplying it with limestone. As the limestone required to operate such a plant would be obtained principally from Baltimore County it would be necessary to get the clayey materials entering into the cement mixture somewhere near at hand. It would be useless, therefore, to consider clay deposits that occurred at considerable distances from the site of the plant unless conditions prevailed making it possible to deliver the clay at the plant at a reasonable cost. The most suitable deposits so far known occur in the Pleistocene, and in the Potomac Group of the Mesozoic.

One of the exposures that may be mentioned where suitable clay for a plant operating on Baltimore County limestone lies to the south of Bodkin Point, in Anne Arundel County. Here the clay can be excavated by steam-shovel and loaded directly into barges and transported up the bay. The thickness of clay deposits exposed along the bay shore in this vicinity varies * from 10 to 30 feet or more in thickness. An analysis of a sample taken by Professor Heinrich Ries ran as follows:

* Md. Geol. Survey, Vol. IV, Part III, p. 390.

ANALYSIS OF PLEISTOCENE CLAY, BODKIN POINT, MD.

Silica (SiO_2)	69.40
Alumina (Al_2O_3)	19.70
Iron oxide (Fe_2O_3)	2.00
Lime (CaO)	.20
Magnesia (MgO)	.60
Alkalies ($Na_2O + K_2O$)	.62
Ignition	7.85

In the above analysis the ratio of silica to alumina is as it should be, between 3.1 and 4.1; while the ratio of iron oxide and alumina to silica is also satisfactory. The amount of magnesia present is insignificant and non-injurious, being many times less than 3 per cent., the allowable upper limit.

Of the Potomac Group the Arundel formation probably affords the largest deposits of clay adapted for use in the manufacture of Portland cement. A very large supply occurs at Monumental on the Baltimore and Ohio Railroad. Most of the clay here * Ries describes as being bluish-gray in color, while the upper portions are often oxidized to red and yellow. There are also some dark organic facies in parts of the bank.

Near Curtis Bay Junction the Arundel clay is also well exposed. Analyses made on material collected here by Ries gave the following results:

ANALYSES OF ARUNDEL CLAYS NEAR CURTIS BAY STATION.

	I.	II.
Silica (SiO_2)	59.70	71.55
Alumina (Al_2O_3)	27.00	17.70
Iron oxide (Fe_2O_3)	2.10	2.25
Lime (CaO)	.60	.60
Magnesia (MgO)	.52	.86
Alkalies ($Na_2O + K_2O$)	1.96	.42
Ignition	8.20	6.50
Total	100.08	99.88

Analysis I. Md. Geol. Survey, Vol. IV, Part III, p. 431.
Analysis II. Md. Geol. Survey, Vol. IV, Part III, p. 433.

Of the two analyses quoted above No. I, though all right in other respects, is too high in alumina. It might, however, be used to advan-

* Md. Geol. Survey, Vol. IV, Part III, p. 434.

tage by mixing it with a limestone of the composition of the "alum stone" at Texas, Md., in which the content of alumina is very low. The clay represented in analysis No. II, is not so high in alumina as No. I, but in this respect is slightly low. In Portland cement manufacture a clay having the composition shown in analysis No. II would prove more satisfactory than a clay analyzing like No. I. Highly aluminous Portland cements are generally discredited, and very properly, too, especially if they are intended for marine work. Many of the clays of the Patapsco formation of the Potomac Group are often sandy. In some of the deposits, however, analysis shows, as in the case of the one quoted below, that the constituents are suitably proportioned and adapted for use in Portland cement:

ANALYSIS OF PATAPSCO CLAY, BACON HILL, CECIL COUNTY.

Silica (SiO_2)	65.70
Alumina (Al_2O_3)	20.30
Iron oxide (Fe_2O_3)	1.00
Lime (CaO)	3.50
Magnesia (MgO)	1.44
Alkalies ($Na_2O + K_2O$)	0.62
Ignition	7.60
Total	100.16

ANALYSES OF LIME AND CEMENT MATERIALS.

BALTIMORE COUNTY.

Name of limestone.	Map No.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).		Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
Marble.	1	Cockeysville.	9.79	....	5.62	....	39.56	6.94	38.69	100.60	70.6	T. M. Price.
"	2	"	2.33	....	0.00	....	52.08	2.39	43.25	100.05	92.5	Jas. Higgins.
"	3	"	0.44	1.22	....	Tr.	30.73	20.87	47.07	100.33	55.0	J. E. Whitefield.
"	4	"	5.57*	....	0.40	....	29.08	20.30	44.26	99.61	47.0	E. A. Schneider.
"	5	"	2.33	....	1.55	....	29.30	20.80	46.00	99.98	52.3	H. J. Patterson.
"	6	"	3.04	1.46	....	.76	31.33	18.66	44.94	100.19	56.1	O. C. Bransky.
"	7	"	3.24	2.06	...	.84	32.20	17.52	44.87	100.83	57.6	O. C. Bransky.
"	8	"	6.73	2.62	....	.56	29.64	19.05	41.90	100.60	52.8	O. C. Bransky.
"	9	"	3.88	3.23	....	1.03	30.68	17.61	44.26	100.69	55.0	O. C. Bransky.
Alum stone.	10	Texas.	.36	....	.20	....	55.72	.19	43.77	100.24	99.5	Zies & Schmidt.
" "	11	"	2.10	....	.61	....	53.70	.61	42.54	99.56	95.8	Zies & Schmidt.
Magnesia stone.	12	"	6.65	....	2.08	....	33.58	15.34	41.32	98.97	60.0	Zies & Schmidt.
Blue stone.	13	"	4.90	...	1.11	....	50.92	1.34	41.03	99.30	90.9	Zies & Schmidt.
Marble	14	"	2.00	....	0.00	....	52.08	2.39	43.44	99.91	92.6	R. S. Williamson.

* Insol.

Summary and Statistics for the Eastern Piedmont.

The calcareous deposits of the eastern Piedmont consist exclusively of thoroughly crystalline marbles which vary in composition from pure lime carbonate to dolomite, and from these pure stones to calcareous schists through the progressive admixture of argillaceous impurities.

The industry based on the working of these materials is practically limited to Baltimore County, about three centers: Cockeysville and Texas, Summerfield, and Glyndon. Of these only the first is of much importance. The quarrying of marble as a building stone is limited almost entirely to Cockeysville. The production of lime is more widespread, although the largest production is from the Texas region. Other smaller operations are reported from various points in the region: From Hess, in Harford County; Fulton, Highland, and Clarksville, in Howard county; and from Dover, Butler, Glyndon, and Texas in Baltimore County. At many points old hillside kilns may be seen which are used intermittently with little or no record of the production.

The total value of the marble and lime produced in the eastern Piedmont in 1908 was $137,561, about half of which was for the lime burned for agricultural and building purposes. Stone for flux was formerly quarried at Texas, but at present at least nine-tenths of the limestone used for fluxing purposes is shipped into the State from West Virginia.

LIST OF LIME AND MARBLE OPERATORS IN THE EASTERN PIEDMONT OF MARYLAND.

BALTIMORE COUNTY.

OPERATOR.	OFFICE.	QUARRY.
Baltimore County Marble & Trading Co.	Baltimore	Summerfield.
Beaver Dam Marble Co.	"	Cockeysville.
Bluemont Stone Co.	Baltimore	Whitehall.
Councilman, Charles A.	Glyndon	Glyndon.
Cockey, Ed. A. & Son	Owings Mills	Gwynnbrook.
Ditman, Wm. C.	Texas	Texas.
Lindsay, Wm. P.	Texas	Texas.
Myers, Wm. F.	Boring	Dover.
Price, M. Bissel (Miss)	Cockeysville	Cockeysville.
Turnbaugh, T.	Boring	Dover.

HOWARD COUNTY.

Baker, G. F.	Marriottsville	Marriottsville.
Walters, G. Dallas	Fulton	Fulton.
Zepp, P. P.	Marriottsville	Marriottsville.

WESTERN DIVISION OF THE PIEDMONT.

The western division of the Piedmont has been separated from the eastern in earlier descriptions by Parrs Ridge. In the present discussion, however, in order to include the crystalline limestones of the headwaters of the Gunpowder River, the northern portion of the line begins near the northeast corner of Carroll County and extends thence southwesterly uniting with the more generally accepted line near Westminster. That portion of the western Piedmont with appreciable amounts of limestone is included in the western part of the Westminster, the major portion of the Taneytown, and parts of the Mount Airy, Ijamsville, and Emmitsburg quadrangles, i. e., in Carroll and the northeastern part of Frederick counties.

The western division of the Piedmont in Maryland is marked topographically, especially in its northern portion where the limestones occur, by a broad upland basin sloping gently to the west. Across this region trend four major ridges of moderate elevation, separated by broad, undulating valleys. These ridges, respectively, from east to west, may be designated as Parrs Ridge, Mt. Vernon Hill, Mt. Zion Ridge, and Johnsville Ridge. A minor ridge, marking the western limits of the more crystalline rocks, borders the Frederick Valley. These ridges owe their elevation to the presence of altered acid and basic volcanics with quartzite in at least two of them.

The drainage west of Parrs Ridge is accomplished by Double Pipe Creek and its tributaries, Israels, Sams, and Turkey-foot creeks. These streams cut through the resistant quartzitic and volcanic ridges and wend their way westward approximately at right angles to the general trend of the limestone valleys which furnish small feeders. The waters of these streams finally mingle with those of the Monocacy.

Geology.

The geological features of the western Piedmont may be summarized as follows: The general trend of the rocks of this region is in every respect similar to that of the rest of the Piedmont on the east and the Appalachian Mountains on the west. The result of the movements which

have given these rocks their present trend is particularly well exhibited in the mapping of the limestones. In the southwestern part of the area the strike is N. 25° to 30° E., but about 4 miles south of Union Bridge the strike of the limestones turns to the northward until in the vicinity of that town the strike ranges from N. 5° to 15° E. Going northeastward, however, from Union Bridge the limestone again appears to strike more strongly to the east and comes to have a general strike of N. 20° to 30° E.

It is thus clear that this region has experienced the same general movements that have affected the rocks of the eastern Piedmont and caused the uplift of the Appalachians further west. The trend of the rocks of the three regions is closely parallel and concentric in arrangement to the same seat of orogenic action, located near and to the southeast of Baltimore.

The relationships existing between the topography, geology, and general structure of this region are most pronounced. With the exception of one or two places where limestone outcrops on and near the hilltops the greater part of the limestone occupies the valley floors. The prominent ridges and the smaller hills are made up mostly of altered volcanics, with quartzites found here and there associated with them. The structure of the valleys in which limestone occurs is generally anticlinal, while that of the ridges is synclinal, and each is more or less overturned to the westward. In both instances the folding has been most complex, and is best exhibited in the minor foldings of the slatey metarhyolites and argillaceous limestones, the latter occurring near and northeast of Linwood.

In the general anticlinal structure of the valleys minor synclinal folds sometimes appear, and often are found infolding the metamorphosed volcanics. Likewise the synclinal ridges exhibit at times small anticlinal folds that result occasionally in exposing at the surface small areas or knobs of limestone. Consequently the anticlines in this section often partake more or less of the nature of anticlinoria and the synclines of synclinoria. Both exhibit smaller foldings in the shape of smaller anticlines and synclines. These smaller flexures are subordinate

to the major folding, and a correct cross-section would therefore represent and show both compound and doubly compound flexures, the extent of the latter depending upon the amount of minor folding.

While the characteristic feature of the structure of the western Piedmont is the prevailing dip eastward and the sharp folding of the rocks into anticlines and synclines, which are overturned to the west, there is good reason to believe that far more faulting has occurred than has heretofore been suspected, although little field evidence has yet been found to indicate the exact location and actual occurrence of such faulting. It has been suggested that this whole region, structurally, is a great fault block which has been faulted up parallel and close to the arbitrary line taken as delineating the western Piedmont on the east, while at the same time similar displacement occurred on the west, roughly paralleling the eastern boundary of the Frederick County Shenandoah limestone, and that the more apparent folds of the region have been imposed subsequent to the faulting.

TYPES OF ROCKS.—Four distinct types of metamorphic rocks, each with its more or less marked varieties, are readily recognized in this western Piedmont region. These are limestones, quartzites, slates, acid, and basic volcanics.

Limestones.—In this region there are three different kinds of limestone, (1) the white crystalline limestone, (2) the variegated limestone, and (3) the argillaceous limestone.

The *white crystalline* limestone is much the most important of the three varieties named, both in distribution and in value. It is a fine-grained crystalline limestone, or marble, that ranges in color from cream to pure white. Analyses made on different samples show a fair degree of uniformity except in the content of magnesia. This varies from a trace to 15 or 20 per cent. The limestone contains few accessory minerals, the principal of which are diopside, tremolite, barite, manganese ores, pyrite, chalcopyrite, bornite, and malachite.

In the case of a number of occurrences to be mentioned later this stone is found unusually free from impurities and suited, not only for making lime for agricultural use and lime to supply the building trades, but for

FIG. 1.—STAUB QUARRY, LITTLE PIPE CREEK, NEAR WAKEFIELD, CARROLL COUNTY.

FIG. 2.—RINEHART QUARRY, SOUTH OF UNION BRIDGE, FREDERICK COUNTY.

VIEWS OF WESTERN PIEDMONT QUARRIES.

all purposes for which an unusually high-calcium limestone is required. Furthermore, this white crystalline limestone may also be employed to advantage in structural work. It takes a good polish and but for lines of weakness that have been developed as the result of pressure it would be unexcelled as a marble for building and decorative purpose and for fine statuary work as well. In the few instances where the rock has not suffered seriously from the sharp folding it may prove valuable for all these purposes.

The *variegated limestone* accompanies the white variety just described, and occurs in zones where the latter has been fractured and recemented. Locally, it is referred to as "calico limestone" in reference to the fact that it is composed of both white and colored fragments, the latter ranging in color from nearly red to a faint pink. The reddish to pinkish parts of the stone are due to the presence of small amounts of manganese and associated iron. These metals seem to have been introduced from below by uprising solutions carrying also in certain cases small amounts of copper. The presence of copper in this variety of the limestone has led to a considerable amount of prospecting and exploitive work which so far has proved disappointing from a commercial standpoint.

The copper ores, which are principally bornite and chalcopyrite, are, however, not wholly confined to the limestones of the characteristic variegated sort. These variegated limestones are always present in the more fractured zones of limestones; but the copper ores, as in the old Liberty Mine southwest of Johnsville, where the limestone carried .75 to 1 per cent. of metallic copper, are found also impregnating portions of the accompanying white crystalline limestone of the type first mentioned. It is interesting to note, moreover, that in these fissured and fractured zones the limestones are also usually inclined to be high in their content of magnesia, and where copper is present are found to be in close association with igneous rocks.

The variegated limestones, as might have been inferred, are also crystalline in character. When cut and polished they form an exceptionally attractive decorative stone. However, they have never been extensively worked for this purpose, although this might be done by em-

ploying suitable channeling machines in certain instances where the rock may be obtained in good marketable shape. The principal defect of the rock is inherent to its manner of origin. The lines of weakness developed as the result of the crushing and fissuring action experienced, still remain in spite of the recementing of the parts and might interfere seriously in the preparation of this stone for actual use.

In chemical composition these variegated crystalline limestones, or marbles, are sometimes very high in calcium carbonate and low in impurities, as shown by the following analysis. Generally, however, they contain 4 or 5 per cent. of magnesia, with varying amounts of silica and alumina.

The following is an analysis of a sample high in calcium carbonate:

ANALYSIS OF VARIEGATED LIMESTONE, UNION BRIDGE.

	No. 15.
Silica (SiO_2)	1.42
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	.74
Lime (CaO)	53.04
Magnesia (MgO)	1.49
Manganese (MnO)	.10
Ignition	43.20
Total	99.99

The *argillaceous limestone* overlies the white crystalline limestone described on a previous page. It varies in color from gray to dark blue. The folding and fracturing which the white crystalline limestone and all the rocks of this region have experienced is in this third type of Piedmont limestone clearly revealed. The minor folding exhibited in the small anticlines and synclines are all more or less compressed and overturned westward.

Besides having been profoundly folded this rock has also been greatly fissured and is streaked with veins both of quartz and calcite. It appears to represent a facies of the white crystalline limestone formation, to which it is superjacent, resulting from the introduction during the period of limestone deposition of land-derived sediments.

Quartzites.—The quartzite of this district is best exposed in the Johnsville Ridge. It is composed of fine grains of quartz originally deposited, of course, as sand that accumulated to form a sandstone. Subsequently dynamic metamorphism has converted the sandstone into a hard quartzite. Quartz veining and secondary cleavage that may be mistaken for true bedding also evidence the tremendous stresses to which it has been subjected. This may be of the same age as the Weverton, which it resembles, but its stratigraphic position was not satisfactorily established during the field study of the nearby limestones.

Slates.—The slates of the western Piedmont, referred to in earlier publications as phyllite, are metamorphosed representatives of normal sedimentary deposits and of igneous rocks, both tuffs and lavas. The relations between the two have not been determined satisfactorily, but in places they seem to grade into each other, suggesting that some, at least, were formed by the contemporaneous deposition of volcanic ash and land-derived materials under subaqueous conditions. The deciphering of their relationships and their relative areal distribution requiring accurate and detailed topographic maps necessitated a postponement of the solution of this question until such maps are available.

That many of the slates are metamorphosed volcanics is shown by the presence of little feldspar crystals, which may be seen by the naked eye, and still better with the aid of a good magnifying glass, and by the relatively high content of the alkalies shown by the analyses below. The content of alkalies of two slates found in contact with the white crystalline limestone, one a typical gray with slight pinkish tint, and the other a characteristic purple, are as follows:

ALKALI DETERMINATIONS OF VOLCANIC SLATES, UNION BRIDGE.

	I.	II.
Soda (Na_2O)	.73	1.51
Potash (K_2O)	6.02	4.18
Total	6.75	5.69

I. Gray slate No. 8, Clemson Slate Quarry.

II. Purple slate, Union Bridge.

The slates of this region differ greatly in the degree of their fissility. The cleavage in some cases is so highly developed, as at Ijamsville, that they have been worked occasionally for more than a century to meet local demands for roofing slates. Attempts have been made to establish a more general quarrying industry, but this has failed since the finished slates lack the "ring" assumed by the trade to be an evidence of permanency. Long exposures on local structures have proven their permanency, but it is improbable that an industry can be established.

Basic and Acid Volcanics.—In addition to the slates of undisputed igneous origin, two other types of igneous rocks that may be readily distinguished in the field are the basic and acid volcanics, the former allied in composition to basalts and diabases and the latter to rhyolites. They are harder and less schistose than the slates and have a fine-grained ground mass in which small crystals of quartz and feldspar, though rarely very prominent are, in most instances, clearly discernible. They are the chief ridge makers of the region. Megascopically, they are exact analogues of certain of the acid and basic eruptives occurring in the Monterey district and that portion of South Mountain which lies in Franklin and Adams counties, Pennsylvania, which have been mapped and studied both in the field and laboratory by Dr. Florence Bascom.*

The basic volcanics are much more widely distributed in the western Piedmont than the acid volcanics, as is also the case in the Monterey district. The age relationship between them has not been satisfactorily determined in either district. Both are found intimately mingled, and the field evidence points to the occurrence in both regions of several sources of lava flow.

In the western Piedmont the chief supply of basic and acid lava was poured out from volcanic vents situated, respectively, in the northern and southern portion of the region.

The *basic volcanics* or "greenstones" of the western Piedmont are characteristically green to greenish-gray in color, owing to the presence of epidote and chlorite. Besides, as has been pointed out, having ana-

* U. S. Geol. Survey, Bull. No. 136.

logues in the Monterey districts the more metamorphosed representatives are strikingly similar to the Catoctin schists which, according to Keith,* have resulted from the alteration of diabase, the latter originating as "a flow of lava along the surface." He describes the Catoctin schist as follows: "The schist was originally a diabase or volcanic rock, composed of crystals of feldspar, pyroxene, olivine, magnetite, and ilmenite. The original massive rock was altered by tremendous pressure and distortion which accompanied folding, so that pyroxene became chlorite, magnetite, and quartz, and the feldspar was partly altered to quartz, chlorite, and muscovite. The new minerals were arranged parallel to one another, and thus the rock became a schist, characterized by the ease of splitting along these minerals." This description would apply equally well as to the origin, metamorphism, and physical characteristics of most of the crumpled schistose, slatey, and epidotic basic volcanics of the western Piedmont.

The basic volcanics of the western Piedmont though usually schistose, compact and fine-grained, and specked with irregularly arranged crystals of quartz and feldspar sometimes occur also with a prominent amygdaloidal structure. The rock in this case is pitted with round, oblong, and irregular-shaped cavities rimmed with iron oxide, which are either empty or partially filled with the minerals calcite, epidote, etc. Because of these features the local name "honey-comb" rock has been adopted, a term not so scientific as it might be, but nevertheless thoroughly descriptive of the characteristics just mentioned.

The *acid volcanics* of the western Piedmont region may be distinguished in the field from the more basic rocks by their difference in color, which ranges with intermediate shades from blue to gray and purple. These rocks occur intimately associated with the basic volcanics or "greenstones" in the northern part of Frederick and Carroll counties, and because of the lack of satisfactory maps the two have not been separated in mapping. Southwestward from Union Bridge to Liberty the acid volcanics increase in prominence and in areal distribution, showing that

* U. S. Geol. Survey, Geologic Atlas, folio 10.

they were originally poured out from one or more volcanic vents to the southward, while on the other hand the basic eruptives originated from a seat of volcanic activity to the north.

The basic and acid volcanics of the western Piedmont lack many of the different phases of crystallization that are exhibited by the eruptives in the Monterey district, being on the whole less porphyritic. When phenocrysts do occur they are smaller and embedded in a finer-grained ground mass. These rocks also give less evidence of flow structure and, so far as has been seen, no evidence of lithophysal or spherulitic textures. If the latter were ever present in the rocks they have either been overlooked or entirely destroyed by the development of the schistosity. As a whole, the volcanics of the Piedmont seem to have suffered more metamorphism than the similar rocks exposed in the South Mountain area, and are consequently more schistose and sheared than their representatives farther west. Nevertheless, there exist large volcanic areas where the rocks of the two regions are practically indistinguishable.

The ancient basic and acid volcanics of the Monterey district are succeeded in the western and central part of the area by the Monterey sandstone. Dr. Bascom thinks that this sandstone, which is Cambrian in age, was deposited upon the underlying eruptives. This would, of course, make the age of the eruptives pre-Cambrian.

GEOLOGICAL SEQUENCE.—The four types of rock described are found overlying each other near the Sauble Quarry on the south end of the Johnsville ridge east of Johnsville. Here the order of superposition from top to bottom is:

Altered volcanics,
Slate,
Limestone,
Quartzite.

If this succession is the normal sequence then all of the rocks are pre-Cambrian, provided the volcanics of the Monterey and western Piedmont represent the same formation as they are supposed to do. Such an interpretation makes the limestone and quartzite older than any similar rocks known in the State.

There are, however, many field observations against this simple interpretation. At several points shales or slates, presumed to be the equivalent of the nearby Martinsburg shales, appear to be interbedded with volcanics, suggesting that some of these, at least, are Ordovician rather than pre-Cambrian. At nearly all points the contact between the limestones and the superincumbent volcanics is not a contact of conformable beds. If this were the case one might expect to find evidences of contact action in the limestones due to the pouring over it of molten lavas. Moreover, the contact plane is often polished and slickensides, proving that it has been a plane of movement and faulting.

Two explanations may be given to the phenomena as now known:

1. The volcanics of the Piedmont may be, in part, at least, of Ordovician age, in which case the limestones may represent metamorphosed equivalents of the nearby Shenandoah group, or

2. The volcanics may be pre-Cambrian and overlie the limestones through thrust faulting along a plane near the upper limit of the limestones, in which case the limestones may be of Loudon or Shenandoah age.

The final solution of the problem must await detailed mapping of the area on satisfactory base maps. The discussion of these formations as sources for material in the manufacture of lime and cement will not, however, be affected by the ultimate solution of the question of their geological age.

TRIASSIC.—Overlying the older rocks of the western Piedmont and the shales, limestones, and quartzites of known Ordovician and Cambrian age in the Frederick Valley are the much younger "red beds" of the Newark formation. Deposits of this age and character are known from Connecticut southward as far as the Carolinas. Whether these rocks were laid down as a continuous formation or in isolated areas is not known. It is generally agreed, however, that they are of shallow-water formation, and that they were laid down in estuaries or lagoons within the continental area.

In Maryland, as elsewhere, the formation consists of red and gray

sandstones and shales, with occasional intercalated beds of calcareous conglomerate or "calico marble."

The Newark beds enter the State from the north between Emmitsburg and Taneytown, with a breadth of 14 to 15 miles, and narrow rapidly southward until they are interrupted by erosion at a point west of Frederick, exposing the underlying Shenandoah limestones faulted upon the Cambrian rocks of Catoctin Mountain. Southward from this point they widen gradually, extending with a slight break in the Valley of the Monocacy into southwestern Montgomery County.

The Newark formation lies unconformably on the Piedmont limestones and associated altered volcanics which are exposed in the northwestern part of the Taneytown quadrangle wherever the Newark formation has been sufficiently eroded. The volcanics, Shenandoah limestones, Martinsburg shales, and Piedmont limestones all pass beneath this formation.

Distribution of Lime and Cement Materials in Western Piedmont.

PIEDMONT LIMESTONES OF CARROLL COUNTY.—The limestones of Carroll County all belong to the western Piedmont type. They occur in narrow anticlinal valleys striking northeast and southwest with a general flexure in their trend to more nearly east and west in the vicinity of Union Bridge.

The exposures in the northeastern corner of the county, along the Hanover Branch of the Western Maryland Railroad, are small and unsatisfactory for large scale operations in lime or cement manufacture. Stone has been quarried and burned for local consumption in the vicinity of Miller, Alesia, and Lineboro, but the quality and quantity are both unsatisfactory. Both north and south of the latter point they have been exposed in mining for iron ore with which the limestone is here associated.

Small lenses of limestone occur southwest of Lineboro in the Bachman Valley, but no deposits of appreciable size are encountered until in the vicinity of Westminster.

FIG. 1.—LIMESTONE QUARRY OF TIDEWATER PORTLAND CEMENT COMPANY, UNION BRIDGE.

FIG. 2.—VIEW OF PROPOSED PLANT OF TIDEWATER PORTLAND CEMENT COMPANY, UNION BRIDGE.

VIEWS OF QUARRY AND PLANT OF THE TIDEWATER PORTLAND CEMENT COMPANY, NEAR UNION BRIDGE, CARROLL COUNTY.

The areal distribution of the exposure is represented in the accompanying map, and where samples have been taken for analysis the location is indicated by numbers corresponding to those assigned the analyses in the accompanying list. By referring to the map and analyses it is possible to gain an accurate idea of the composition of the stone at a given locality.

North of Westminster is the *Orndorf Quarry*. This is reached by the road from Westminster to Stoner, and is about 3 miles north of the former. This is a small quarry, and while a considerable quantity of stone has been quarried in the past, and the lime made from it sold chiefly for agricultural purposes, it is capable now of very little further development because of its heavy overburden of volcanics.

The limestone occurrences within the limits of the northern half of the Taneytown quadrangle though geologically important are, however, from a commercial viewpoint, insignificant. Their distribution is limited and is restricted to the vicinity east of Mayberry and west of Silver Run.

Quarries have been opened and operated on white crystalline limestone both to the north and the southwest of Westminster. Those located in the latter direction are centered about Spring Mills, which is on the Western Maryland Railroad about 1¾ miles west of Westminster. There are four quarries here, but only two are in operation. Both of these are small and neither is capable of large development because of the heavy overburden of soil and volcanics. The first of these to be considered is the *Geo. W. Albaugh Quarry*, which is situated on the north side of the Western Maryland track ¾ of a mile east of Spring Mills, or, in other words, between Spring Mills and Westminster. The geographic position of the quarry and the composition of the stone are both indicated by "No. 1" on the map and in the table of analyses, respectively. By consulting the reference number in the table of Carroll County analyses, it will be seen that so far as the quality of the limestone is concerned it would fully meet the requirements for use in the manufacture of Portland cement. The quantity of material that could be economically quarried would, however, be insufficient. On the northwest side of the quarry, which would be the natural direction for development, the white

crystalline limestone, exhibiting here and there bands of blue limestone, is capped by a heavy cover of volcanics that forbids much further work in this direction.

The quarries located at the points Nos. 2 and 3, respectively, northeast and southwest of Spring Mills, have long since been abandoned because of the small exposures, and because, too, of the heavy overburden of volcanic material and the consequent high cost of quarrying at both these places. The quality of stone at each of these small quarries is such as to make it adapted to mix with a suitable shale in the manufacture of Portland cement, but in both occurrences there is a deficiency in the quantity of the material susceptible of economic working.

The only quarry to the southeast of Spring Mills and Warfieldsburg, that is in operation, is known as the *Roop Quarry*. This is opened on the white crystalline limestone, which is much fissured and accompanied by some limestone of the "calico" variety. The former forms the floor of the little valley that extends nearly all the way from Spring Mills to Warfieldsburg. The quarry is situated on the west side of this valley and is opened under the brow of the hill, an outlier of Parrs Ridge, that rises in this direction. The working face is from 15 to 35 feet high, with a cover, which is mainly at the south end of the quarry, ranging from 10 to 18 feet in thickness. The dimensions of the quarry are as follows: 85 feet northeast and southwest and 30 to 50 feet northwest and southeast. The hard, pink-streaked white limestone that is obtained here and used mostly for manufacture into lime is high in magnesia, containing 15.30 per cent. of magnesia (see analysis No. 4).

Of the small quarries that have been opened east of Wakefield and west of Parrs Ridge, the only one perhaps worth mentioning is situated about a mile nearly due north from Avondale, and about midway between Copps Branch and the road passing along the west flank of Parrs Ridge. This is known as the *B. F. Shriver Quarry*, and its precise location on the map is indicated by the number 5.

The white crystalline limestone of this quarry is intensely fissured and is overlain on the west by a thick mantle of volcanic rock of the amygdaloidal or "honey comb" type, prohibiting, except at a considerable

cost, any further extensive development of this side of the quarry. The Shriver Quarry is no exception to the fact, to which attention has already been called, that when the limestones of this region occur much fissured and intimately associated with volcanics, they are usually high in magnesia. The content of magnesia in the Shriver Quarry is slightly over 10 per cent. (see analysis No. 5).

William Carbaugh's Quarry (No. 6) is located just outside of the town of New Windsor on the south side of the south fork of Pipe Creek and east of the small stream that enters the creek within a stone's throw north of the quarry. Here the limestone is high in magnesia, as is found to be the case nearly everywhere, that the western Piedmont limestone is either greatly fissured or is closely associated with the less altered of the volcanics. The limestone here lies between the volcanics. Where the former is superjacent to the volcanic material on the west there is a marked difference in the dip of the two rocks. The dip of the limestones is 15° E. while that of the planes of schistosity of the volcanic is 70° to 80° E. In the old, abandoned quarry due west, located on the south side of the juncture of the road from the quarry to the turnpike, this volcanic is again in contact with the limestone, which, as previously stated, lies between beds of altered rock of igneous origin. The structure here is strongly suggestive of step faulting, accompanied and followed by folding.

Two other quarries opened on white crystalline limestone are located on the northwest side of the ridge that extends from New Windsor northeastward by Wakefield. They are situated on the west bank of Little Pipe Creek. The first, the Geo. R. Staub Quarry (No. 11), being about $\frac{3}{8}$ of a mile north of the juncture of Turkey Foot Run and Pipe Creek. The other, the small quarry (No. 12) owned by Dennis A. Smith, is nearly opposite the point where the run flows into the creek.

The *George R. Staub Quarry* (No. 11) is located but a short distance up the creek from the Smith Quarry. In the past the Staub Quarry has been extensively worked and the stone burned into lime, but it now lies idle, chiefly because of the expense attendant upon removing the overburden of residual soil which varies in thickness from 3 to 15 feet. The

length of the quarry in the direction parallel to the creek is close to 300 feet, and ranges in width, east and west, from 50 to 150 feet. The average breast is about 22 feet. As can be seen from the Carroll County table of analyses the stone obtained here is low in iron, alumina, and silica but high in magnesia.

The stone obtainable from the *Dennis A. Smith Quarry* (No. 12) is low in magnesia and would, but for its distance from the railroad, the low-working face, and the expense of quarrying, be suitable for manufacture into Portland cement. The breast of stone is about 15 feet high and is covered above with nearly 3 feet of residual soil. It dips 50° E., and burns into a very good grade of lime.

At all of the quarries south of New Windsor the limestone is of the white crystalline variety, and as usual is so greatly fissured because of the stresses, pressure, and distortion it has experienced, that the original bedding planes and their direction of dip are partially, if not wholly, obscured by other planes and fissures superinduced by the forces just mentioned. Nevertheless, in spite of the secondary cleavage, the original stratification planes, if they have been correctly identified, may be said to dip from 10° to 15° east.

About a mile and a half farther up the narrow limestone valley drained by the small stream passing the Carbaugh Quarry there is another quarry that has been opened and operated on a small scale, which is known as the *A. Rupp Quarry*. Its position on the map is shown by the number 7.

A quarter of a mile, more or less, down the stream from the Rupp Quarry is an old opening where most of the stone susceptible of being worked economically has been removed. Neither this quarry nor the Rupp Quarry, where the quality of the stone is very good indeed, is capable, however, of yielding a large tonnage of stone without the removal of a thick overburden on all sides which would make the cost prohibitive were it attempted to work either place much more extensively than at present. The breast of stone, moreover, in both these quarries is low, ranging from 10 to 20 feet in height. This might be increased by deepening the quarries, but in either instance any anticipated

advantage that might result would be more than counterbalanced by the extra expense so entailed.

Limestone is exposed both to north and south of Linwood, and has been worked at both the quarry sites indicated by numbers 8 and 9. These quarries, however, at present are not in operation. The former, *Haines Quarry,* is situated, as shown, on Little Pipe Creek just to the north of Linwood. The limestone is here hard and white and high in magnesia, though low in silica, alumina, and iron. The quarry may be seen on the north side of the road directly west of Linwood Station. At the Haines Quarry the breast of stone is 25 to 30 feet thick. Formerly it was quarried and burned into lime, but during the past few years the quarry has lain idle. It is stated that the quarry was abandoned owing to the fact that the stone is hard and expensive to quarry, and for the further reason that the lime produced failed to meet with favor among those using it for agricultural purposes.

A small quarry has been opened, but is idle at present, on the white crystalline limestone exposed on the *Shriver* place, southwest of Linwood, at the point (No. 8) indicated on the map, with a breast of about 20 feet. This working face, however, might be increased with further development. Analysis shows that the rock here is too high in magnesia for Portland cement, though fairly suitable for making agricultural lime.

The limestones up Roop Branch, to the east of Clear Ridge, have been quarried at different points, but the stone being highly argillaceous burns to a very unsatisfactory grade of lime. The only quarry now in operation on this type of limestone is situated about a mile and a quarter east of Uniontown, and about an eighth of a mile south of the Uniontown-Westminster road. The quarry and two kilns (No. 10) are owned by Fielder G. Gilbert. The limestone in the *Gilbert Quarry* is blue to gray in color and streaked with veins, both of quartz and calcite, the latter usually predominating. The limestone is extremely shaly and the intense stresses to which in the past it has been subjected are indicated by the complicated minor folding and veining to be seen throughout the quarry. The working face at the south end of the quarry, where the rock passes upward into beds increasingly argillaceous and shaly, is a little

over 20 feet. The lime produced, although of a low grade, meets with a ready sale for agricultural purposes to supply a local demand, but only because of the distance of the surrounding country from better limestone deposits and from the railroad, and the consequent greater expense of obtaining a lime of better quality.

Argillaceous limestone, extremely shaly and impure, occurs on the farm of *Mr. Frank Englar* (No. 13) north of the Western Maryland Railroad and about midway between Union Bridge and Linwood. With this exception all of the limestones near Union Bridge are of the white crystalline variety accompanied here and there by the variegated type. The location of the quarry where this shaly limestone has been worked and burned to a limited extent into lime for agricultural use, in spite of its impurities, is indicated on the map by the number 13, opposite which, in the table of analyses, may be found the composition of the sample.

Northwest of the station at Union Bridge limestone again is well exposed on the *Clemson place,* from the points 15 to 17, shown on the map. It is here a hard white limestone that has been much fissured and contains at unequal intervals infolded fragments of altered volcanic. The working face above the level of the meadow-land which lies between it and Sams Creek ranges from 15 to 30 feet. With the exception of sample 17, which represents the stone in the small, abandoned quarry just west of the Clemson house, the rest of the limestone, as may be seen by consulting the table of analyses, is high in magnesia. It would be unsuited for Portland cement. It is perhaps best adapted for use as ballast or as road metal, and for these purposes it could probably be profitably quarried.

PIEDMONT LIMESTONES OF FREDERICK COUNTY.—Limestone lenses, similar in all respects to those of Carroll County, continue to occur southward, extending across Frederick County in a gradually narrowing zone from Sams Creek on the north, through Liberty and Unionville, to the vicinity of New Market on the south. With a single isolated exception, near Park Mills, no crystalline limestones of the western Piedmont type are exposed south of the main line of the Baltimore and Ohio Railroad.

The areas of exposure trend in a northeast and southwest direction of long elliptical or irregular shape, and are found in greatest breadth and abundance along a line following the road from east of Woodsboro, through Liberty, to a short distance east of Unionville. The limestone areas on the northern border of the county, near Union Bridge, are the only ones situated near the railroad, and therefore potentially available for cement manufacture. The deposits more removed from the lines of transportation, while unavailable for larger operations acquire an increased value as a source of stone for lime burning to meet local demands for agricultural purposes.

Some of the purest limestone in the State is found in the vicinity of Union Bridge. This is confined chiefly to a narrow belt passing east of the town, where the limestone is from 100 to 150 feet thick and dips about 20° east and strikes N. 15° to 20° E. It is worked at the Wolfe Quarry of the Tidewater Portland Cement Company on Sams Creek; and at the Haines Quarry about a half a mile to the northwest of Union Bridge. Between these points the overburden of residual soil is, however, too thick to make the opening of a quarry profitable.

The *Wolfe Quarry* is located in Frederick County (Nos. 1-5) about ½ mile east of where the Johnsville Turnpike, leading south from Union Bridge, crosses Sams Creek. The quarry, when visited, was about 165 feet in length in a north and south direction, and about 130 feet wide, measured east and west. The working face of pure white crystalline limestone was from 35 to 40 feet high. The limestone in this quarry dips 20° east, and on the eastern side of the quarry passes under a heavy mantle of purplish to gray slate which forbids extensive development in this direction. In the northwest end of the quarry variegated limestone is seen accompanied by infolded chloritized slate. Here also it was observed that the stone contained a small amount of malachite.

Throughout the Wolfe Quarry the limestone is very much fissured. It breaks and shatters easily under the hammer, but this is due to the lines of weakness that were developed during its geological history because of the stresses and distortion that it has undergone as the result of the folding and faulting characterizing the structure of this entire section.

Analyses (1-5), inclusive, give the composition of the limestone in different parts of the quarry, and show that on the whole it is extremely pure and unusually low in silica, alumina, and iron, making it an exceptionally fine stone for manufacture into lime, and suitable also both for use in the blast furnace and for open-hearth flux. Moreover, its composition adapts it for use in the manufacture of Portland cement, which could be made here by combining it to form a mixture with the overlying slate and the nearby Triassic shale. A further description of the development of this property by the Tidewater Portland Cement Company is given on pages 370 to 377.

The *Haines Quarry* (No. 7) is opened, as has been stated on a previous page, on the same high-grade bed of limestone as the Wolfe Quarry. This quarry is owned by Wm. Haines, of Union Bridge. A 27-foot face is worked and, as at the Wolfe Quarry, the stone dips about 20° towards the east. The overburden on the east is heavy, and as a result most of the rock is taken from the west end of the quarry, where the residual soil is not so thick nor so expensive to remove. Three stone kilns of the continuous mixed-feed type, are located on the west side of the quarry in which practically all the stone that is quarried is burned into lime.

About 1¾ miles southwest of Union Bridge, on the *Rhinehart property,* a quarry has been opened within the past two years for purposes of quarrying marble. The crystalline limestone is here characterized by a faint creamish tint, is fine-grained, and takes a beautiful polish. The quarry is located on the map between the numbers 8-13, which also denote the numbers given the samples which were taken for chemical analyses.

This crystalline limestone or marble has a workable thickness of a little over 220 feet. As at present developed by the Maryland Cremo Marble Company, the only marble operator in the western Piedmont, the width of the quarry is about 60 feet. The marble is quarried by means of Sullivan channelers, which are here used to cut or channel the stone at right angles to the strike. The strike here is N. 15° E., and the dip 50° east.

FIG. 1.—CRYSTALLINE LIMESTONE, FINE-GRAINED AND CREAMY WHITE, TIDEWATER PORTLAND CEMENT COMPANY QUARRY, UNION BRIDGE.

FIG. 2.—ARGILLACEOUS OR SHALY LIMESTONE, FOLDING BROUGHT OUT BY WEATHERING, CLEAR RIDGE.

TYPICAL LIMESTONES OF WESTERN PIEDMONT.

The accompanying Plate XIV, Fig. 2, gives a very correct idea of the amount and manner of the development at the time the photograph was taken, during the summer of 1907. As shown in the photograph this marble appears to be absolutely white. As a matter of fact, instead of being a hard and dead, lusterless white it has a beautiful cream tone. As a building and decorative stone it is one of the most attractive and pleasing the writers have seen in Maryland.

ARGILLACEOUS MATERIAL.—Among the sources of nearby argillaceous material available for mixture with the crystalline limestones of Carroll and Frederick counties are the red and gray shales of the Newark formation and the slaty volcanics.

Judging from their color these appear much higher in iron than is really the case, as will be shown by the following analyses, one of which was made on a sample of the sandstone and the other on a sample of the shale:

ANALYSES OF TRIASSIC SANDSTONE AND SHALE, ROCKY RIDGE, MD.

	I Sandstone.	II Shale.
Silica (SiO_2)	70.01	64.19
Alumina (Al_2O_3)	12.48	16.25
Iron oxide (Fe_2O_3)	4.62	5.61
Lime (CaO)	2.78	1.80
Magnesia (MgO)	1.30	2.42
Ignition	3.99	4.55
Undetermined	4.82	5.18
Total	100.00	100.00

I. Just east of Rocky Ridge. Anal. Zies and Schmidt.
II. 2 miles east of Rocky Ridge. Anal. Zies and Schmidt.

As can be seen from the above analyses the shale, though high in iron, would nevertheless be suitable to use in the manufacture of Portland cement. These shales outcrop on the Western Maryland Railroad just west of Union Bridge and might be used to advantage with the high-grade limestones that occur there, the two furnishing a mixture that should burn to an excellent cement. Less ferruginous shales occur nearby and could be added to the mixture if it should be necessary.

The slaty volcanics which usually flank the limestone valleys in the western Piedmont vary in composition, but are at times suitable for use

in Portland cement manufacture. The composition of two of these from the vicinity of Union Bridge are as follows:

ANALYSES OF SLATY VOLCANICS, UNION BRIDGE.

	I.	II.
Silica (SiO_2)	45.80	45.73
Alumina (Al_2O_3)	19.06	15.85
Iron oxide (Fe_2O_3)	11.73	26.91
Manganese (MnO)	.10	.04
Lime (CaO)	1.15	1.77
Magnesia (MgO)	11.71	2.78
Alkalies ($Na_2O + K_2O$)	3.86	2.84
Ignition	8.02	4.18
Total	101.43	100.10

I. Altered volcanic, ¼ mile E. Union Bridge. Anal. Zies and Schmidt.
II. Purple volcanic, Little Pipe Creek ½ mile N. Union Bridge. Anal. Schmidt.

*The Tidewater Portland Cement Company.**

Property and Materials.—The property consists of 181 acres, of which at least 50 per cent. is composed of limestone and shale. The limestone used varies in composition from 95 to 99.5 per cent. of carbonate of lime and from a trace to 4 per cent. carbonate of magnesia. The shale which directly adjoins the limestone, and which can be secured, if desired, from a common quarry, is also of excellent quality. Analyses of the raw materials follow:

ANALYSES OF LIMESTONE, WOLFE QUARRY, UNION BRIDGE.

Silica (SiO_2).	Oxides of alumina and iron ($Al_2O_3+Fe_2O_3$).	Lime (CaO).	Magnesia (MgO).	Ignition.	Totals.	Carbonate of lime.
4.46	0.52	51.94	1.10	42.03	100.05	92.75
1.40	0.24	53.75	1.06	43.41	99.86	95.98
6.40	0.62	51.04	.65	40.84	99.54	91.14
1.72	0.56	53.45	1.08	43.19	100.00	95.45
0.28	0.24	54.45	1.34	44.27	100.58	97.23
1.26	0.36	54.35	.64	43.41	100.02	97.05
1.08	0.20	54.89	.46	43.63	100.26	98.01

ANALYSES OF SHALE.

Silica (SiO_2).	Alumina (Al_2O_3).	Iron oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).
58.00	22.28	8.40	0.42	2.06
52.74	23.44	11.30	0.20	2.33
54.54	24.24	9.80	0.85	1.78

* Data furnished by R. K. Meade.

The indications are that there is upon the various properties a practically inexhaustible supply of limestone. The shale deposits are very extensive, and the quantity of this available is sufficient to more than outlast the limestone deposits. This quarry is also discussed on page 367.

Quality of the Cement.—In order to determine definitely the suitability of the materials for the manufacture of Portland cement, they were mixed in the proper proportions, ground, burned and again ground, and the properties of the resulting product examined, just as would be done in the manufacture of Portland cement on a large scale. The cement so made was found to be equal to the best American Portland cements now on the market. The analysis and tests are given below:

CHEMICAL ANALYSIS OF CLINKER.

Silica (SiO_2)	19.94
Alumina (Al_2O_3)	7.57
Iron oxide (Fe_2O_3)	3.45
Lime (CaO)	65.58
Magnesia (MgO)	1.69
Sulphur trioxide (SO_3)	0.26
Loss on ignition	0.62

PHYSICAL PROPERTIES OF THE CEMENT.

Fineness: (Standard sieves and method of sieving.)
Residue on the No. 100 ....95.2
Residue on the No. 200 ....80.1

Setting Time: (Gilmore's needles.) Air and water 72° F.
Initial set................1 hour and 45 minutes.
Final set.................4 hours and 45 minutes.

Constancy of Volume: (Soundness.)
Five-hour steam test, Pats remained firm and hard and showed no signs of distortion, checking, cracking or disintegrating.
Six-hour boiling test, Pats remained firm and hard and showed no signs of distortion, checking, cracking or disintegrating.

Tensile Strength:

Time in air	24 hrs.	24 hrs.	24 hrs.	24 hrs.	24 hrs.
Time in water		6 days	6 days	27 days	27 days
Total age	24 hrs.	7 days	7 days	28 days	28 days
Composition	Neat	Neat	*Sand	Neat	*Sand
Strength	350	810	275	1025	410
In pounds	380	825	260	1000	425
Per sq. inch	375	845	255	1005	415
Average	372	827	263	1010	417

* One part cement to three parts standard Ottawa sand.

White Portland Cement.—The limestone is unusually free from iron, and hence may be used for the manufacture of white Portland cement. Deposits of limestone sufficiently pure to be used for this purpose are very rare, and this is one of the few deposits in the country suitable for this purpose. A sample of white Portland cement made from this limestone had the following composition and properties:

CHEMICAL ANALYSIS OF WHITE CLINKER.

Silica (SiO_2)	22.12
Alumina (Al_2O_3)	7.56
Iron oxide (Fe_2O_3)	0.28
Lime (CaO)	64.10
Magnesia (MgO)	1.03
Sulphur trioxide (SO_3)	0.21
Loss on ignition	0.74

PHYSICAL PROPERTIES OF THE WHITE CEMENT.

Fineness: (Standard sieves and method of sieving.)
Residue on No. 100 .... 94.8
Residue on No. 200 .... 81.2

Setting Time: (Gilmore's needles.) Air and water 72° F.
Initial set .... 1 hour and 30 minutes.
Final set .... 5 hours.

Constancy of Volume: (Soundness.)
Five-hour steam test, Pats remained firm and hard and showed no signs of distortion, checking, cracking or disintegrating.
Six-hour boiling test, Pats remained firm and hard and showed no signs of distortion, checking, cracking or disintegrating.

Tensile Strength:

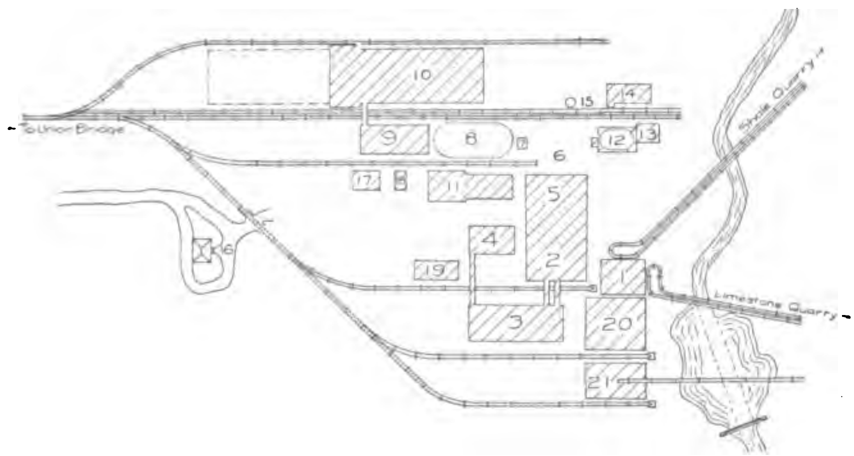
Time in air	24 hrs.	24 hrs.	24 hrs.
Time in water		6 days	6 days
Total age	24 hrs.	7 days	7 days
Composition	Neat	Neat	*Sand
Strength	245	650	225
In pounds	200	645	240
Per sq. inch	215	670	220
Average	220	655	228

* One part cement to three parts standard Ottawa sand.

These tests show the white Portland cement made from this limestone to be the equivalent not only of any white Portland cement now on the market, but also to be the equal in strength of the best brands of Portland cement.

Description of Plant.—The two raw materials lie directly to the south of the plant, a small creek separating their quarries from the mill site. The location can hardly be improved upon, both raw materials lying as they do, adjacent to the mill site, and there being sufficient water in the creek at all seasons of the year to supply the needs of the plant.

The plant will consist of a mill of 2400 barrels' daily capacity for the manufacture of Portland cement, a mill with a capacity of 600 barrels



1. Crusher.
2. Driers.
3. Grinders.
4. Mixing mill.
5. Kilns.
6. Driers.
7. Clinker tower.
8. Clinker pile.
9. Clinker mill.
10. Warehouse.
11. Coal mill.
12. Clinker pile, white cement.
13. Clinker mill, white cement.
14. Warehouse, white cement.
15. Oil tank.
16. Office.
17. Machine shop.
18. Blacksmith.
19. Storehouse.
20. Lime plant.

Fig. 21.—Plan of arrangement of buildings, Tidewater Portland Cement Company, Union Bridge.

for white Portland cement, and a lime plant with a capacity of about 60 tons of lime and hydrated lime.

The limestone and shale, after quarrying, will be conveyed in steel cars to the crushing house. In this will be located one No. 9, and three No. 6½ Gyratory crushers, all being driven by large motors. The cars will be drawn to the plant by means of an electric cable and will discharge directly into the No. 9 crusher, which will reduce the material to pieces about six inches in diameter. From this crusher the material will pass into a large elevator which will distribute the material into the three

smaller crushers, where it will be crushed so that all the product will pass through a 2½-inch ring. From the crusher part of the material will be carried into storage for the night run and part will go directly to the driers. The storage will have a capacity of about 1500 tons in order to prevent shut-downs due to rainy weather and similar causes.

The shale will be brought in by means of cars which will be loaded by a steam shovel at the shale bed. These cars are to be hauled to the mill by an electric tramway and the shale there crushed in a No. 6½ crusher, from which it will pass to the storage and driers. There will be three driers, seven feet in diameter and 50 feet long, two of which will be used for limestone and one for shale. These driers are to be located directly back of the kilns in order to utilize the waste heat from the kilns for drying the stone, thus saving coal. Leaving the driers, the material, still separated, will be carried to Krupp ball mills, of which there are to be three, two for limestone and one for shale. These ball mills granulate the material. From them the shale and limestone will be passed to storage bins, which will have a capacity of 5000 tons of raw material; 3000 tons of limestone and 2000 tons of shale.

The material will be drawn from the storage bins in proper proportions as determined by analysis and mixed by automatic mixing machines. After this, it will be finely pulverized by a battery of nine Fuller mills, which are considered to be the most improved machines at the present time available for pulverizing.

Leaving the Fuller mills, the material will be carried to the five kilns, four of which will operate on Portland cement and the fifth on white Portland cement. The material fed into the kilns by means of a screw conveyor will discharge directly into an inclined feed-pipe leading into each kiln. The kilns will operate with the Matcham natural draft system of coal-burning.

Leaving the kilns, the clinker will be lifted into the coolers, one of which will be provided for each kiln. These will be 6 x 60 feet, and the clinker will be cooled by a current of air drawn through them by a stack. On leaving the coolers, the clinker will be conveyed to a clinker storage. This latter will consist of an overhead conveyor arranged to deposit the

clinker in piles, where it will be exposed to the atmosphere and allowed to season and soften. Underneath the clinker piles are to be tunnels in which operate belt conveyors.

From the storage the clinker will be carried to the finishing mill. Here it will be first crushed by means of ball mills, and then ground in fourteen Fuller mills. Before being ground the clinker will be mixed with the proper percentage of gypsum. The Fuller mills will grind a much finer cement than can be produced with other types of grinding machinery, and it is expected that the product of the Tidewater Portland Cement Company's plant will be ground so fine that 85 per cent. of it will pass a No. 200 mesh sieve, thereby yielding 10 per cent. more cementing materials in a barrel of Tidewater cement than is present in ordinary cements, only 75 per cent. of which will pass a No. 200 mesh sieve.

After being ground the material will be passed to the stock house, where it will be stored and seasoned ready for shipment. At one end of the stock house will be the bagging house and loading platform. The cement will be bagged by means of Bates valve bag machines, which automatically bag and weigh the cement.

The coal for burning will be brought in on cars from the mines in West Virginia and dumped into a hopper below the tracks. From this it will be carried up to the coal storage by means of an elevator. From the storage it will be drawn by gravity to a set of rolls which will crush the larger lumps. It will then pass into the coal driers, which will be of the Meade type. After being dried the coal will be pulverized in Fuller mills and carried over to the kilns. The plant will be electrically driven throughout.

There will be three large cross-compound engines, directly connected to a large alternating generator. There will also be in this department one relay unit for break-down devices, a motor generator and an engine-driven generator for exciting the generators. There will also be a switchboard.

In the boiler house there will be six 404-H. P. water-tube boilers. These boilers will be fired by means of Lehigh stokers. The cars will be brought in alongside the power house on a trestle and dumped into a

hopper. From this hopper the coal will be lifted by means of an elevator to the top of the boiler house and discharged to a long continuous bin above the stokers. There will also be the usual boiler feed-pumps, condensers, etc.

In connection with the cement plant there will be a fully equipped machine-shop for repairing any machinery of the type used in the plant.

The buildings will all be constructed of steel with expanded metal and concrete siding. The roofs of all buildings, except the boiler house and kiln building, which will be of corrugated iron, will be of matched flooring covered with composition roofing.

Each grinding unit will have its own bin, which in most cases will be sufficient for from 12 to 24 hours' run. The kilns will be provided with large individual bins, each of which will hold sufficient material for 24 hours' run. All the conveying will be done by means of bucket-chain elevators, and either screw or belt conveyors. The installation throughout will be such as to save labor and fuel.

The machines for grinding the raw material from which the white Portland cement is to be manufactured will be located in the same room as that used for grinding the ordinary Portland cement. The mills used for grinding the white Portland cement clinker will be in a separate building and the stock house for the white Portland cement will be separated from the stock house for the gray Portland cement. Oil will be used for burning the white Portland cement, and a large tank for storing this will be situated some distance to one side of the plant, on the hill. The oil will be delivered to this tank by means of tank cars.

The lime plant now built consists of five Keystone kilns. The stone is carried to the top of these by means of a runway and side-dump cars. The firing floor is provided with tracks and cars for distributing the coal in front of the various furnaces. The coal is brought in alongside the building and dumped into a hopper. From this it is carried up and dumped into the cars by means of an elevator. Below the firing floor is situated the cooling floor. The lime is taken from the kilns and spread upon this to cool. When it is desired to hydrate the lime, this is first passed through a Sturtevant Open-Door Crusher. From this it goes to

FIG. 1.—" HONEYCOMB ROCK," AMYGDALOIDAL CATOCTIN SCHIST OR BASIC VOLCANIC ROCK, WESTMINSTER.

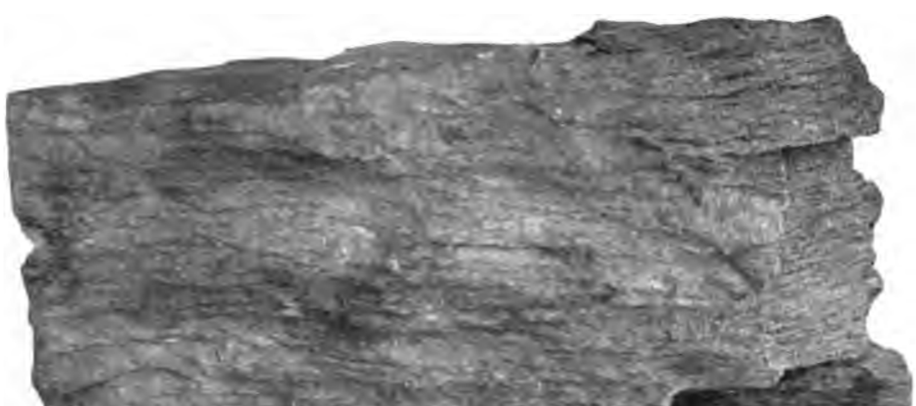


FIG. 2.—SLATY METARHYOLITE, OR ACID VOLCANIC ROCK, WITH FELDSPAR PHENOCRYSTS, SAM'S CREEK.

TYPICAL VOLCANIC ROCKS OF WESTERN PIEDMONT.

a hydrating machine of the Kritzer make, where it is mixed with water. After being hydrated, the unhydrated material is separated by means of two Newaygo screens. The tailings are sent to the cement mill and used in place of limestone for cement manufacture. The product of the screens is delivered into two large bins above the bagging machines. These are of the Bates valve bag type. The lime plant is driven by its own engine and boiler.

Location.—The plant of the Tidewater Portland Cement Company is situated on the Western Maryland Railroad only 45 miles from tide, and thus is admirably located to distribute its products at low cost, not only to Baltimore and Washington but by water transportation over a wide district along the Atlantic Coast. No cement works yet constructed in this country are more favorably located for this purpose than the plant of the Tidewater Portland Cement Company.

Summary and Statistics for the Western Piedmont.

The best grade of limestone in the western Piedmont near transportation facilities is located in the vicinity of Union Bridge where it can be and is quarried at a lower cost, probably, than at any one of the competing points along the Western Maryland Railroad in the Piedmont. At Linwood and New Windsor the limestones are either too high in magnesia or else the amount available is limited and costly to obtain. Both conditions usually prevail at each of these points. On the other hand, in the vicinity of Unionville, the stone is of little value either as to quality or quantity. It is used to supply, in part, a small local demand. Around Westminster where there is limestone, both of good and indifferent quality, white crystalline limestones occur, ranging from a low to high content of magnesia, and often other impurities in varying amounts. The heavy overburden of residual soil and volcanics encountered in all of the quarries near Westminster prohibits a very large development except at an excessive and unprofitable cost.

The total value of lime produced in the western Piedmont in 1908 amounted to over $16,000, the largest single operator being at Union Bridge. The value of limestone produced and sold for ballast, build-

ANALYSES OF LIME AND CEMENT MATERIALS OF WESTERN PIEDMONT.

CARROLL COUNTY.

LIMESTONES.

Name of limestone.	Map No.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
White.	1	Geo. W. Albaugh.	Springville.	3.84	1.44	.80	50.43	1.85	41.55	99.43	89.8	M. R. Schmidt.
"	2		"	8.06	3.80	1.68	47.84	1.48	37.74	100.05	84.8	M. R. Schmidt.
"	3		Spring Mills.	2.50	.61	.58	52.62	1.40	42.48	100.19	93.5	M. R. Schmidt.
"	4	Roop.	"	1.66	.82	.67	35.92	15.80	45.27	99.64	64.1	M. R. Schmidt.
"	5	B. F. Shriver.	"	.81	.46		42.81	10.19	45.65	99.42	76.8	M. R. Schmidt.
"	6	Wm. Carbaugh.	New Windsor.	1.03	.52		41.27	11.73	45.55	100.10	73.7	Zies & Schmidt.
"	7	Roop-Ziles.	"	.68	.51		53.53	1.92	43.49	100.18	95.1	Zies & Schmidt.
"	8	Haines.	Linwood.	2.56	.45		50.19	4.28	43.12	100.60	89.6	Zies & Schmidt.
"	9		"	1.02	1.57	.85	40.51	11.74	43.72	98.91	72.4	E. G. Zies.
"	10		Uniontown.	16.25	4.81	1.68	40.46	2.95	33.69	99.84	72.8	M. R. Schmidt.
"	11	Geo. R. Staub.	New Windsor.	1.07	1.04	.38	42.87	10.54	44.93	100.83	76.5	M. R. Schmidt.
"	12	D. A. Smith.	"	4.94	2.64	.39	48.25	2.17	41.52	99.91	85.1	E. G Zies.
"	13		Union Bridge.	23.61	5.73	1.41	35.04	8.49	30.04	99.82	62.5	M. R. Schmidt.
"	14		"	2.17	.89		54.82	.10	42.60	100.08	98.0	Zies & Schmidt.
"	15	Clemson.	"	.87	.56	.72	34.16	16.27	46.26	98.84	62.7	M. R. Schmidt.
"	16	"	"	1.78	.84	.38	44.03	8.28	44.51	99.82	78.3	E. G. Zies.
"	17	"	"	1.45	.66		50.36	1.06	43.68	97.16	89.7	M. R. Schmidt.

ARGILLACIOUS MATERIALS.

Name of limestone.	Map No.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
Sandstone.			Rocky Ridge.	70.01	12.48	4.62	2.78	1.30	8.99	95.18*	....	
Shale.			"	64.19	16.25	5.61	1.80	2.42	4.55	94.82*	....	
Altered volcanic.			Union Bridge.	45.80	19.06	11.73	1.15	11.71	8.02	101.43	....	Zies & Schmidt.
Purple volcanic.			"	45.73	15.85	26.91	1.77	2.78	4.18	100.08	....	M. R. Schmidt.

FREDERICK COUNTY.

LIMESTONES.

Name of limestone.	Map No.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
	1	Tidewater P. C.	Union Bridge.	1.08	.20		54.89	.46	43.63	100.26	98.0	R. K. Meade.
	2	" "	"	3.90	2.02	.64	52.40	.72	41.86	101.54	93.48	H. P. West.
	3	" "	"	3.50	0.41	.09	52.59	.95	42.31	99.96†	93.5	Penniman & Browne.
	4	" "	"	1.39	.45		55.27	.35	43.02	100.48	98.7	Zies & Schmidt.
	5	" "	"	0.62	0.28	0.02	54.89	.38	43.70	99.91†	98.4	Penniman & Browne.
	6		"	4.32	1.86	.46	46.00	5.29	41.64	99.84†	81.9	Penniman & Browne.
	7	Buffington.	Johnsville.	1.81	.78		53.88	1.07	42.52	100.06	96.0	E. G. Zies.
	8	Rhinehart.	Union Bridge.	0.99	3.00	0.15	51.73	1.69	42.55	100.17†	92.0	Penniman & Browne.
	9	"	"	0.49	0.04	0.05	54.12	1.32	43.98	100.05†	96.2	Penniman & Browne.
	10	"	"	2.44	0.45	0.17	53.76	0.35	42.82	100.04†	95.9	Penniman & Browne.
	11	"	"	5.02	0.46	0.13	51.12	1.49	41.88	100.20†	90.9	Penniman & Browne.
	12	"	"	0.31	0.23	0.16	53.04	2.08	44.34	100.20†	94.4	Penniman & Browne.
	13	"	"	3.51	0.88	0.18	47.63	4.78	42.87	100.15†	84.8	Penniman & Browne.
	14	Norris.	Norris.	3.77	1.03	.28	49.80	2.90	42.25	100.03	88.8	Zies & Schmidt.
	15	Clemson.	Union Bridge.	1.42	.74		53.04	1.49	43.20	99.89	94.4	Zies & Schmidt.

* Alkalies not determined. † Includes P_2O_5.

ing, concrete, and road metal probably did not exceed $3000, making the value of the lime and limestone produced in this section for 1908 aggregate approximately $20,000. The list of operators located in the western Piedmont follows below:

WESTERN PIEDMONT.

CARROLL COUNTY.

OPERATOR.	ADDRESS.	QUARRY.
Carbaugh, Wm.	New Windsor	New Windsor.
Dutterer, John T.	Silver Run	Silver Run.
Everhart, Wm. H.	Westminster	Bachman's Mill.
Fritz, Mordecai	Uniontown	Uniontown.
Goodwin Lime Co.	Westminster	Westminster.
Haines, Wm.	Union Bridge	Union Bridge.
Leppo, Wm. A.	Silver Run	Silver Run.
Myers, John W.	New Windsor	New Windsor.
Shriver & Co., B. F.	Westminster	Westminster.
Wakefield Mill & Lime Co.	"	"
Wareheim, Denton S.	"	Cranberry.
Yingling, Wm. R.	"	Westminster.

FREDERICK COUNTY.

Crum, John D.	Walkersville	Daysville.
Kramer, D. K.	Mt. Pleasant	Mt. Pleasant.
Tidewater Portland Cement Co.	Union Bridge	Wolfe.*

* One mile south of Union Bridge.

FREDERICK VALLEY.

Frederick County is the leading lime-producing county in the State, and contains the raw materials upon which this industry is based more abundantly than any other county east of the Blue Ridge. Its limestones and shales also furnish the necessary material for the manufacture of Portland cement. The proximity of limestones and argillaceous materials in the Frederick Valley to two large markets, Baltimore and Washington, make this an especially attractive section for the building of Portland cement plants. Portland cement is a bulky product, and every mile saved in the matter of transportation adds just so much to the dividends of the company manufacturing it.

The limestones of the Shenandoah group or the "Valley limestones," as they are sometimes called, occur in Maryland on both sides of the Blue Ridge. They consist of gray, massive limestones of very great aggregate thickness, and on the east side of the Blue Ridge form the floor of the Frederick Valley, where they are extensively quarried and burned into lime. Most of the Shenandoah group of limestones are high in

magnesia, the bane of the cement manufacturer, but nevertheless there are many quarries and occurrences where the magnesia content is found to be quite low.

GEOGRAPHICAL LIMITS.

The Shenandoah limestones of the Frederick Valley, as may be observed from the accompanying map, cover a longitudinal-shaped area extending from Woodsboro on the north, where it emerges from beneath the Newark formation, to the Potomac River, about 7 miles south of Buckeystown. It attains its maximum areal width of about 6 miles in the vicinity of Frederick, and its least of about ¾ of a mile where it crosses the Potomac. On the west it passes under the Newark formation, except in one instance where the latter has been removed by erosion, when it is in faulted contact with the underlying Harpers shale, and on the east is in juxtaposition with altered volcanics and sedimentary shales and slates of undetermined age.

The northern portion of the Frederick Valley is known as Glade Valley, and is so called from the stream that flows south and drains this portion of it. Woodsboro station, on the Northern Central Railway, is situated at its northern end.

The city of Frederick occupies, approximately, the center of the valley, and is reached from the north by the Northern Central Railway and from the south by the Baltimore and Ohio Railroad, via Frederick Junction. A branch line runs from here into Frederick, while the alignment of the main track is eastward. At Frederick Junction the main line bridges the Monocacy, and within the limits of the Ijamsville quadrangle parallels the course of Bush Creek, crossing slates, altered volcanics, and other rocks of undetermined age and origin.

These two railroads furnish the transportation facilities for all the lime operators of this section, bringing them their fuel and carrying their finished product to market. Large quarries and batteries of kilns are in operation to the east of Frederick, located along and near the branch road leading to Frederick Junction. Plants for the manufacture of lime are in operation also in the Frederick Valley on the main line of the Baltimore and Ohio at and near Limekiln, Keller, and Buckeys-

town. There are no large quarries between Buckeystown and Daubs, where the limestone of the Frederick Valley becomes hidden on the west by overlying Triassic shale and sandstone. Between these two stations limestone of good quality undoubtedly occurs, but has never been extensively exploited, probably because of the thickness of the residual soil concealing the underlying limestone, which, but for this overburden, could be readily quarried and utilized. Broadly speaking, the amount and thickness of residual soil is less north of Frederick than it is either on the east or south, and the operators to the north of the city, on the line of the Northern Central Railway, near Walkersville and Woodsboro, are put to less expense in their operations for the removal of overburden and water.

At present there are no cement plants in the Frederick Valley, but, as may be seen from the table of analyses, suitable material occurs and may be found at points definitely known, while there are many others that remain to be located, and could be found also were further expense incurred to pay for the time and effort necessary to find them. This is in reference, of course, to the limestone. Shale, which occurs on all sides of the valley in abundance, and often of suitable character to mix with the limestone, might be located definitely likewise.

The juxtaposition of limestone and shale, low freight rates to the leading markets, and facilities for transporting fuel, all go to make the Frederick Valley one of the most attractive parts of Maryland for the location of Portland cement plants.

GEOLOGY.

The limestones of Frederick County are of three major types: The crystalline limestones and marbles of the western Piedmont, exposed in the eastern part of the county, which have been described already as extending from the northeastern limits of the county to the vicinity of New London and New Market; the Shenandoah or valley limestones in the central part of the county; and the insignificant intercalated calcareous conglomerates and limestones of the Newark formation. Of these the second is the most important.

The Shenandoah group of limestones of Frederick are a local representative of the widely extending limestone series forming the great valley of Virginia, the Hagerstown Valley, of Maryland, and the Cumberland Valley, of Pennsylvania. The detailed discussion of these formations in the description of Washington County supplements the following concise description more applicable to the Frederick Valley.

Of the seven limestone formations, aggregating over 10,000 feet in thickness, recognized in Washington County, only the upper two or three have been found in Frederick County, and of these only the uppermost—the Chambersburg—aggregating probably less than 600 feet has been mapped east of the Blue Ridge. The areal limits of this formation against the overlying Martinsburg shales and the underlying limestones of questionably Stones River and Beekmantown age have been shown on the map. The exposure of all these formations is further limited by the overlying much younger Newark "red beds" and the contiguous older shales and volcanics on the western and eastern borders of the valley. All of the beds between these limits are proven by their fossils to be of Ordovician age.

The Chambersburg formation consists of impure limestones, argillaceous limestone, and calcareous shales. The beds richer in lime lie beneath the shaly beds. The whole formation appears to be intermediate both in composition and stratigraphic position between the overlying Martinsburg shales and the underlying lime-rich Stones River and Beekmantown limestones. The chief economic value of the Chambersburg lies in its argillaceous character, and in certain beds which are naturally almost perfect Portland cement mixtures. Suitable material for cement manufacture appears to be abundant and accessible.

The underlying Stones River and Beekmantown formations are freer from argillaceous matter than the Chambersburg, but increasingly magnesian in character passing downward. The beds just beneath the Chambersburg are nearly pure limestone, and these are followed by equally pure but thinner beds alternating with harder ones richer in magnesium. The beds high in lime, when exposed at the surface, may be recognized by the white, smooth, rounded surfaces of the ledges and

the velvety texture and characteristic dove color of freshly fractured fragments. The fact that these purer limestones yield a deep red soil well-suited to the cedars which grow upon it, has given to them the local name of "cedar stone" in areas where this formation is well developed.

The eastern limit of the limestone has usually been placed at the base of the low ridge of shales forming the eastern boundary of the valley, but recent investigations have shown the presence of numerous narrow and poorly exposed areas of limestone in minor valleys lying east of the easily recognized ridge of Martinsburg shales. The poor exposures resulting from the heavy cover of "wash" from the hills on either side do not offer the proof that these isolated exposures are connected, but the topography, geological structure, and areal distribution of the region indicate the presence of a continuous band of limestones between the first ridge on the west bordering the eastern side of the valley, and the shales and volcanics on the east representing the western limits of the rocks characterizing the western Piedmont.

DISTRIBUTION OF LIME AND CEMENT MATERIALS IN FREDERICK VALLEY.

Calcareous Materials.

WOODSBORO DISTRICT.—Two large limestone quarries are situated about a mile north of Woodsboro, and are separated by the diabase dike that crosses the railroad south of Le Gore Station. The quarry on the east side of the railroad, indicated by Nos. 16-21, and nearer the station, is owned and operated by the Le Gore Lime Company, while the other (Nos. 22-24) is the property of S. W. Barrick & Sons.

Several varieties of limestone are exposed in the *Le Gore Quarry,* which range in color from blue to light gray, and in texture from semi-crystalline to very fine grained. Samples were taken of several of these beds, which differed in physical appearance, in order to determine by analysis if possible whether the color and texture were in any way diagnostic of the composition. It was discovered that the light-gray limestones were the purest, and were lower in magnesia the softer the color tone and the more satiny the luster of the fresh-fractured surface.

Below are listed four of the samples from the Le Gore Quarry, with a brief description of their color and fracture, together with the numbers referring both to the points where the samples were taken, as shown on the map, and to their analyses in the table, giving the composition of various samples of limestone and shale coming from Frederick County:

ANALYSES OF LIMESTONES, LE GORE QUARRY, LE GORE.

	No. 16.	No. 18.	No. 19.	No. 20.	No. 21.
Silica (SiO_2)	4.21	4.55	2.85	8.51	2.34
Alumina (Al_2O_3)	1.18	1.61	.44	2.77	.92
Iron oxide (Fe_2O_3)			.71	.78	
Lime (CaO)	52.76	49.40	54.00	38.72	51.80
Magnesia (MgO)	.75	3.25	.49	6.45	2.43
Ignition	41.46	41.68	42.25	40.07	42.75
Total	100.36	100.49	100.74	97.30	100.24

No. 16. Dove to light gray limestone, irregular to conchoidal fracture, partially crystalline, medium fine grained and compact.

No. 18. Bulk sample representing 150 feet.

No. 19. Very light gray chalcedony like limestone. Conchoidal fracture, fine grained to amorphous.

No. 20. Blue-gray limestone. Rough irregular fracture, and dull and faint and brownish saccharoidal luster.

No. 21. Gray limestone, semiconchoidal fracture, compact but slightly crystalline.

All of these samples, with the exception of the blue-gray limestone, ran fairly low in magnesia, as will be seen from the analyses.

The breast of stone worked in the Le Gore Quarry ranges from 30 to 60 feet in height. The beds strike N. 20° E. and dip 70° E., and the quarry is worked westward, or in a direction opposite to the dip. A bulk sample, representing the 150 feet of stone nearest the railway, namely, that on the westernmost side of the quarry, and including the several varieties of limestones mentioned above, ran, on analysis, as indicated. The magnesia is slightly high in the analysis, but the limestones it represents could be used in the manufacture of Portland cement in conjunction with either the shales on the west side of the valley or with the Triassic shales encountered along the line of the railroad a short distance north of Le Gore.

FIG. 1.—KILNS AND QUARRY OF S. W. BARRICK & SONS, LE GORE.

FIG. 2.—QUARRY AND KILNS OF LE GORE COMBINATION LIME COMPANY, LE GORE.

VIEWS OF FREDERICK VALLEY QUARRIES.

Nearly all of the limestone taken from this large quarry is burned into lime in a battery of 17 stone-constructed kilns located between the quarry and the railroad. By selecting and working beds of different composition the owners find it possible to produce limes that range in their content of calcium oxide from 96 to 98 per cent., and of a quality that will meet the various demands of the consumers.

The *Barrick Quarry* is opened on the west side of the railroad and northwest from the Le Gore Quarry. The diabase dike, already mentioned, passes between the two. The quarry in a northwest and southeast direction is from 350 to 375 feet wide, and in the direction of the strike (N. 15° E.) 400 to 500 feet long.

The breast of stone in this quarry is from 20 to 30 feet high, and is, therefore, not so high as in the neighboring Le Gore Quarry, but it is worked somewhat more systematically since the working face is kept in better alignment. About 75 per cent. of the limestone exposed here is from blue to dove in color, while the rest is almost white to very light gray, together with a small proportion along the eastern limits of the quarry of blue to grayish limestone, mottled with patches yellowish to brown in color, the so-called "gray-back" limestone.

A bulk sample taken at right angles to the strike and representing 350 feet of the Barrick stone showed, on analysis, a composition closely analogous and suitable for the same purposes as that of the Le Gore Quarry. The analysis follows below:

ANALYSIS (No. 23) OF A BULK SAMPLE FROM S. W. BARRICK AND SONS' QUARRY. LE GORE.

Silica (SiO_2)	4.63
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	1.13
Lime (CaO)	49.45
Magnesia (MgO)	3.01
Ignition	41.79
Total	100.01

The so-called "gray-back" limestone was found to contain 6.72 per cent. of magnesia and a small amount (0.63 per cent.) of carbonaceous

matter. The complete analysis (No. 24) will be found in the table of analyses.

The lime kilns which are of the stone-constructed mixed-feed continuous type are built on the east side of the quarry. One of the batteries is on the edge of the quarry and west of the railroad, and the other on the opposite side of the railroad. The former is equipped with a mechanical appliance whereby the lime may be drawn from the kilns and loaded directly from them into the cars.

The first quarry south of Woodsboro on the line of the Northern Central Railroad is located 250 yards or more northwest of *McAleer* Station, and is owned by Frank M. McAleer. The working face where the rock is somewhat fissured is low, averaging about 15 feet with a soil overburden ranging in different parts of the quarry from 5 to 15 feet in thickness. On fresh fracture the limestone quarried here is blue in color but weathers on the surface to a light gray. It is burned in a battery of three kilns located at the station and on the west side of the railroad. The beds dip 55° E. and strike N. 20° E. A sample (No. 25), including the working face and representing in all 100 feet in a southwesterly direction perpendicular to the strike, showed a rather high content of silica, but was low in magnesia.

WALKERSVILLE DISTRICT.—No quarries have been opened between McAleers and Woodsboro or between the former and Walkersville, about 2 miles south of McAleers, because between these points the limestone is generally covered by a heavy mantle of residual soil.

The only remaining important limestone quarry between Woodsboro and Frederick is at Fountain Rock, a little over a mile, along the Northern Central Railway, south of Walkersville. With the exception of faulting, which is here absent, the quarry shows clearly the general structure of the Shenandoah limestone throughout the Frederick Valley. As can be seen from the accompanying illustration the limestone of the *Fountain Rock Quarry* is folded first into a syncline at the eastern end of the quarry, which in the west is followed by the anticline shown on the left side of the picture.

The breast of stone at the east end of the quarry is 48 feet. The lower 28 feet of gray to dove-colored limestone was included in one sample (No. 31), while the upper bench of 20 feet of blue limestone was represented by a separate sample (No. 30).

ANALYSES OF LIMESTONE, FOUNTAIN ROCK QUARRY, FOUNTAIN ROCK.

	No. 30.	No. 31.
Silica (SiO_2)	6.65	3.62
Alumina (Al_2O_3)	1.30	.93
Iron oxide (Fe_2O_3)	.51	.30
Lime (CaO)	47.99	46.41
Magnesia (MgO)	3.09	5.82
Ignition	40.47	42.59
Total	100.01	99.67

The upper bench, as both the weathering in the field and the analyses made in the laboratory show, is higher in silica than the underlying beds. The analyses also bring out the further fact that the content of magnesia in the lower bench of stone is higher than that of the superjacent 20 feet. They average 4.5 per cent. of magnesia, which would make it difficult to manufacture the stone into a Portland cement that could meet the rigid requirements of the standard specifications unless some purer stone were introduced into the mixture. This could be obtained from the quarries near Woodsboro.

Some of the limestone from this Fountain Rock Quarry is sold for ballast and concrete work, but most of it is calcined and the product sold largely to farmers for liming their land. The burning, heretofore, has been carried on in the old-fashioned stone-constructed type of continuous kiln, but the Fountain Rock Lime Company, which owns both the quarry, formerly known as the Stimmell Quarry, and the kilns, is replacing the old battery with steel-clad, brick-lined kilns, not only more modern in design but better, producing, as they do, a higher-grade product and effecting also a considerable saving in the cost of fuel.

FREDERICK DISTRICT.—Three limestone quarries are situated near Frederick, one to the east of the town, and two to the southeast. All are at present in operation. The quarry at No. 34 is owned and operated by Gilmer Schley. Of the two southwest of Frederick, the larger

is operated by the M. J. Grove Lime Company, which also owns quarries at Limekiln, while the smaller quarry was owned until recently by the Frederick Lime and Stone Company. Both quarries on the south are on the south side of the Baltimore and Ohio Railroad, the former, the M. J. Grove Lime Company's quarry, being about 1½ miles from the Baltimore and Ohio station in Frederick, and the latter, the Frederick Lime and Stone Company, approximately ¾ of a mile southwest of the same point.

An exposure of argillaceous, thin-bedded limestone occurs at a short distance east of the Baltimore and Ohio station in Frederick, which at one time was used either for ballast, as a road metal, or for burning into lime, as is evidenced by a small, abandoned quarry on the south side of the railroad about 200 yards beyond the station. A bulk sample taken perpendicular to the strike, or, in other words, at right angles to the direction of the dip, and representing every inch of a stratigraphic thickness of 82 feet showed, on analysis, the following composition:

ANALYSIS (No. 35) OF ARGILLACEOUS LIMESTONE, FREDERICK.

Silica (SiO_2)	9.65
Alumina (Al_2O_3)	2.18
Iron oxide (Fe_2O_3)	.90
Lime (CaO)	46.42
Magnesia (MgO)	3.04
Ignition	38.43
Total	100.62

The composition and physical character of the limestone whose analysis is given above make it an exceedingly suitable material to use with a shale of low content of magnesia in the manufacture of Portland cement. Shale of this character occurs on the line of the Baltimore and Ohio Railroad just across the river from Frederick Junction. The strike of the limestone at the locality here mentioned is N. 25° E. with a dip of 25° E. Limestone of a similar character is exposed about midway between Frederick and Frederick Junction, and again between the midway point and the Junction itself.

The *Gilmer Schley Quarry*, as has been stated, is directly east of Frederick. On this property there are two quarries, the old one now

practically abandoned because of the heavy overburden and the necessity of pumping in order to keep the quarry free from water. It is located to the northeast of where Carroll Creek crosses the Frederick-New Market road. West of this point, and about 550 feet north of the road just mentioned, is the battery of four kilns in which is calcined most of the rock quarried from the new quarry opened at a distance of between ¼ and ½ of a mile further down the stream, from which the stone is hauled in carts to the kilns.

The stone in the new Schley Quarry opened at the point on the map marked 34 ranges in color from light blue through dove to gray, and has a working face of from 25 to 30 feet. Compared with the old quarry the cover of residual soil in this new quarry, though from 3 to 6 feet in thickness, is small, inasmuch as that of the old quarry back and east of the kilns varies from 15 to more than 20 feet. The width of the quarry is about 60 feet. The chemical analysis of a bulk sample of the quarry shows it to be unusually high in magnesia, containing, as it does, over 17 per cent.

Passing from Frederick to Frederick Junction, on the Baltimore and Ohio Railroad, the quarry formerly owned by the Frederick Lime and Stone Company, and now the property of the *Tabler Lime and Stone Company*, is the first quarry on the west of the railroad just outside of Frederick, and 2000 feet north of the Grove Quarry, the next quarry to be described. The color of the stone is blue and weathers to a dove color. It dips 10° to 12° E., and the strike of the bed is N. 50° E. At the north end of the quarry, namely, the end nearest the railroad, the breast of stone is 32 feet. Differential weathering has occurred at both ends of the quarry, and particularly at the south end. At the north end it is shown by the more or less corrugated appearance of the stone, the softer and purer material occupying the furrows, while the harder and more siliceous forms small ridges parallel to the bedding.

The following is an analysis made for the Tabler Lime and Stone Company of sample of their lime submitted for analysis to Dr. Charles F. McKenna, 221 Pearl Street, New York, N. Y.:

ANALYSIS (No. 36) OF LIME FROM TABLER LIME AND STONE CO.'S QUARRY, FREDERICK.

Silica (SiO_2)	2.09
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	.72
Lime (CaO)	91.48
Magnesia (MgO)	1.78
Ignition	4.11
Total	100.18

The same company supplied the writers with the following physical tests made on the limestone taken from their quarry:

CRUSHING TESTS ON LIMESTONE FROM THE TABLER LIME AND STONE CO.'S QUARRY AT FREDERICK.

Ore piece. size.	Failed at pounds.
1″ × 1″ × ⅝″	17,000
1″ × 1″ × 1⅝″	29,950
1″ × 1″ × 1″	32,800
1″ × 1″ × 1″	32,140

The above tests were made by L. E. Kennedy, 11 Broadway, New York.

The stone occurring at the southern end of the Tabler Lime and Stone Company Quarry is covered with a heavy mantle of soil formed as the result of weathering and extending down between less soluble "horses" or masses of solid stone.

A sample taken of the 32-foot breast at the north end of the quarry gave, on analysis, the following:

ANALYSIS (No. 37) OF LIMESTONE, TABLER QUARRY, FREDERICK.

Silica (SiO_2)	8.17
Alumina (Al_2O_3)	2.69
Iron oxide (Fe_2O_3)	.48
Lime (CaO)	47.27
Magnesia (MgO)	2.34
Ignition	38.70
Total	99.65

In the above analysis

$$\frac{SiO_2}{Al_2O_3+Fe_2O_3} = 2.5$$

or, in other words, the ratio silica to alumina plus ferric oxide is about

correct. Moreover, the magnesia is low and other deleterious impurities are absent. A Portland cement mixture could, therefore, be formed by a combination of this limestone with the shale occurring on the line of the Baltimore and Ohio Railroad within ½ mile east of Frederick Junction.

The M. J. Grove Lime Company's Quarry on the Baltimore and Ohio Railroad, between Frederick and Frederick Junction, is the largest quarry near Frederick. The cartographic position is shown on the map by the numerals 38-39. It is the second quarry met with going from Frederick to Frederick Junction, on the Baltimore and Ohio Railroad, or traveling along the Frederick-Baltimore turnpike, is the first quarry beyond the Tabler Quarry already described.

At the center of the quarry the limestone is folded into an arch or anticline, and is flanked on either side by synclines. The lower 20 feet of limestone at this point is dove-colored, and is surmounted by a darker limestone that is blue to light gray in color. The working face varies from 30 to 50 feet in different parts of the quarry, depending on the amount of overburden, which ranges from 10 to 20 feet. Samples were taken both on the east and south side of the quarry. The sample taken on the east side of the quarry, where the color of the limestone is blue and the stone is more or less crystalline, was obtained at the foot of the incline leading from the crusher down into the quarry. Its composition is given under No. 38, while the composition of the sample from the south end of the quarry will be found under No. 39.

ANALYSES OF LIMESTONE, M. J. GROVE'S QUARRY, FREDERICK.

	No. 38.	No. 39.
Silica (SiO_2)	23.86	2.47
Alumina (Al_2O_3)	.89	.77
Iron oxide (Fe_2O_3)	.53	
Lime (CaO)	36.65	43.64
Magnesia (MgO)	5.10	9.50
Ignition	33.46	43.97
Total	100.49	100.35

The latter represents the 80 feet of limestone on the west flank of the anticline mentioned as being exposed on the south side of the quarry.

Both these analyses show a content of magnesia too high to permit the limestone obtained in the Grove Quarry to be used in the manufacture of Portland cement, though it burns into a very good grade of lime. The company operates 17 kilns and has others of the steel-clad type in course of construction.

In order to get a suitable working face the owners of the Grove property have been obliged to deepen the quarry, and, as a result, have encountered water, necessitating the installation of pumping machinery to prevent the quarry being flooded. In the exploitation of this quarry, as in other limestone operations in the Frederick Valley, topography has helped very little in furnishing a natural working face to the quarry.

BUCKEYSTOWN DISTRICT.—The principal limestone quarries south of Frederick are situated at Limekiln and near Buckeystown. Those at the former place are on the west side of the Baltimore and Ohio Railroad, while those west of Buckeystown are opened up along the right-of-way, and are about 1¾ miles southwest, along the track, from Limekiln.

The quarries at Limekiln are owned and operated by the *M. J. Grove Lime Company,* which also owns, as previously mentioned, the large quarry and kilns between Frederick and Frederick Junction. The stone burned here in a battery of seven kilns is obtained from two separate quarries, neither very large, and both having a more or less heavy overburden of residual soil. The first and larger one of these quarries is a little more than ¼ of a mile east of the lime kilns and station, while the other is close to the track, and just west of the company's store. The smaller quarry near the station (Nos. 42-44) has a working face of about 30 feet at its southwest end. Because, however, of its depth, and especially for the reason that there is a heavy overburden which has to be removed on the quarry's east side, it has been practically abandoned in favor of the larger quarry first mentioned. The latter has a working face at the northeast end of the quarry of about 35 feet, while at the southern end the stone is much weathered and there is a heavy overburden of residual soil. In both these quarries the stone is blue to gray in color, and in the case of the stone from the larger quarry (analyses Nos. 40-41) is high in magnesia. There is less magnesia in the stone

FIG. 1.—STIMMEL QUARRY, FOUNTAIN ROCK LIME COMPANY, FOUNTAIN ROCK.

FIG. 2.—SOUTH END OF QUARRY, M. J. GROVE LIME COMPANY, FREDERICK.

VIEWS OF FREDERICK VALLEY QUARRIES.

in the quarry nearest the kilns (analyses Nos 42-44), but this advantage is counterbalanced by the extra cost of obtaining it.

ANALYSES OF LIMESTONE, M. J. GROVE'S QUARRIES, LIMEKILN.

	No. 40.	No. 41.	No. 42.	No. 43.	No. 44.
Silica (SiO_2)	0.85	3.76	3.90	0.31	3.53
Alumina (Al_2O_3)	0.72	0.88	0.36	0.14	0.99
Iron oxide (Fe_2O_3)		0.50			0.12
Lime (CaO)	32.89	34.06	52.23	52.35	50.70
Magnesia (MgO)	18.60	15.82	1.30	2.84	3.13
Ignition	46.11	44.09	42.23	44.35	41.99
Total	99.17	99.11	100.02	99.99	100.56

There are a number of limestone quarries around Buckeystown, the largest and most important of which is the *O. J. Keller Lime Company's Quarry* situated east of the line of the Baltimore and Ohio Railroad 1¾ miles south of Limekiln. The limestone beds here range from blue to gray in color, and have been folded into an arch or anticline. Near the center of this arch, which has a span of about 300 feet, that being the length of the quarry in an east and west direction, the same pressure that produced the anticline has superinduced a synclinal flexure upon the major fold. The breast of stone varies in different parts of the quarry, but averages close to 30 feet. Samples from the southeast (No. 49), northwest (No. 48), and northern (No. 47) parts of the quarry showed, respectively, on analysis, the following contents of magnesia, 3.46 per cent., 2.83 per cent., and .66 per cent., or an average of 2.31 per cent. magnesia for the whole quarry. The complete analyses of these samples follow:

ANALYSES OF LIMESTONE, KELLAR QUARRY, BUCKEYSTOWN.

	No. 47.	No. 48.	No. 49.
Silica (SiO_2)	13.94	3.03	6.49
Alumina (Al_2O_3)	1.38	.95	.86
Iron oxide (Fe_2O_3)	.30		.47
Lime (CaO)	47.02	50.85	47.40
Magnesia (MgO)	.66	2.83	3.46
Ignition	36.73	41.81	41.17
Total	100.03	99.47	99.45

From these it is evident that the quality of stone makes it well adapted to manufacture into Portland cement, using the shale found on the Baltimore and Ohio just east of where the railroad after leaving Frederick Junction crosses the Monocacy River.

Argillaceous Material.

The manufacturer of Portland cement in the Frederick Valley may use either the Triassic shale on the west or the metamorphosed sedimentary and igneous slates occurring on the east. The Triassic shales are best situated for use near and north of Woodsboro on the line of the Northern Central Railway, though they also may be had on the Baltimore and Ohio Railroad at and southwest of Daubs Station, but the altered volcanics and metamorphosed sedimentaries are nearer to the operations around Frederick, and hence in starting a plant there a suitable shale deposit would be looked for along the line of the Baltimore and Ohio Railroad east of Frederick Junction.

Analyses of both varieties of shale mentioned above are given below. The analysis marked 8 was made on a sample of slate obtained 1860 feet east of the east bank of the Monocacy, where it is crossed by the Baltimore and Ohio Railroad bridge. The last 60 feet of this 1860 was represented in the sample, and the analysis shows that it fully meets all the requirements for use in the manufacture of Portland cement. The point where this sample was taken is indicated on map by the figure 8.

Samples of the Triassic shales were taken along the line of the Western Maryland Railroad at the points shown on the map as Nos. 1-5. Though they contain from 5 to 7 per cent. ferric oxide, nevertheless their content of iron is less than one would expect from their deep red color. They are low in magnesia and generally low in alumina, the latter being supplemented by ferric oxide. As 10 * per cent. is considered the upper limit of the amount of ferric oxide that a ferruginous shale may carry and still be used for Portland cement, it will be evident from

* Bull. III, Ohio Geol. Survey, p. 76.

what has been said above and from results given in the table of analyses, that certain of the Triassic shales would form a suitable cement material. The analyses of these shales are given below:

ANALYSES OF SHALE, FREDERICK COUNTY.

	No. 1.	No. 3.	No. 5.	No. 9.
Silica (SiO_2)	60.33	70.01	58.74	66.08
Alumina (Al_2O_3)	18.28	12.48	18.13	17.63
Iron oxide (Fe_2O_3)	7.12	4.62	6.15	4.62
Lime (CaO)	1.01	2.78	3.08	.37
Magnesia (MgO)	3.75	1.30	2.34	1.03

1. Partial Analysis, Shale. W. Md. Ry., Loys.
3. Partial Analysis, Shale. W. Md. Ry., Graceham.
5. Partial Analysis, Shale. W. Md. Ry., Graceham.
9. Partial Analysis, Shale. B. & O. R. R., E. Frederick Junct.

FREDERICK COUNTY.

ARGILLACEOUS MATERIALS.

Name of shale.	Map No.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Alkalies.	Ignition.	Total.	Analyst.
Triassic.	1		Loys.	60.83	18.28	7.12	1.01	3.75	n.d.	4.18	94.67	Schmidt.
Triassic.	2		Graceham.	64.19	16.25	5.61	1.80	2.42	n.d.	4.55	94.82	Zies.
Triassic.	3		"	70.01	12.48	4.62	2.78	1.30	n.d.	3.99	95.18	Zies.
Triassic.	4		"	56.57	16.03	7.81	4.64	2.53	n.d.	7.30	94.48	Schmidt.
Triassic.	5		"	58.74	18.13	6.15	3.08	2.34	n.d.	6.21	94.95	Zies.
	6		Johnsville.	47.85	16.04	20.19	0.60	6.07	3.94	5.07	99.76	Zies.
	7	Tidewater P. C.	Union Bridge.	58.41	22.27	8.31	0.09	0.73	6.42	3.66	99.89	
	8	Clemson.	"	n.d.	n.d.	n.d.	n.d.	n.d.	5.69	n.d.	....	
	9		Frederick Junct.	66.08	17.63	4.62	.37	....	....	2.49	92.22	Zies.

SUMMARY AND STATISTICS FOR FREDERICK VALLEY.

The lime and limestone industry in the Frederick Valley is centered around the following five points, Woodsboro, Walkersville, Frederick, Buckeystown, and Limekiln, the last two on the Baltimore and Ohio Railroad south of Frederick, and the first two on the Northern Central Railway north of Frederick. Both of these railroads enter Frederick.

Frederick County, as usual, ranked first in the annual production of lime, the value of the product being in the neighborhood of $200,000, while the value of the limestone sold for other purposes amounted to nearly $50,000. The annual products resulting from the quarrying of limestone often reached or exceeded a total value of over $300,000.

FREDERICK COUNTY.

LIMESTONES.

Name of limestone.	Map No.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
Chambersburg.	16*	LeGore.	LeGore.	4.21	1.18		52.76	.75	41.46	100.36	93.8	Zies & Schmidt.
"	17		"	.50	.60		55.10	.24	43.56	100.00	95.9	H. J. Patterson.
"	18		"	4.55	1.21	.40	49.40	3.25	41.68	100.49	87.9	Zies & Schmidt.
"	19		"	2.85	.44	.71	54.00	.49	42.25	100.74	96.0	M. R. Schmidt.
"	20		"	8.51	2.77	.78	38.72	6.45	40.07	97.30	69.0	E. G. Zies.
"	21		"	2.34	.92		51.80	2.43	42.75	100.24	93.2	Zies & Schmidt.
"	22	Barrick.	"	2.33	10.10		45.69	2.67	38.81	99.60	81.2	T. M. Price.
"	23		"	4.63	1.13		49.45	3.01	41.79	100.01	88.0	Zies & Schmidt.
"	24		"	11.30	7.08	1.57	33.97	6.72	37.55	98.19	60.6	Zies & Schmidt.
"	25	McAleer.	McAleer Station.	9.23	2.69	.85	46.74	2.24	38.17	99.42	83.2	E. G. Zies.
"	26		Unionville.	.50	. . .	. . . .	55.72	. . . .	42.98	99.20	98.7	
"	27		Walkersville.	0.89	.50		54.88	.37	43.41	100.05	97.5	
"	28	Stimmel.	Fountain Rock.	4.31	.90		45.80	6.21	42.78	100.00	81.7	
"	29	"	"	4.78	1.40		52.36	.14	41.37	100.00	93.2	
"	30	"	"	6.65	1.30	.51	47.99	3.09	40.47	100.01	85.4	E. G. Zies.
"	31	"	"	3.62	.93	.30	46.41	5.82	42.59	99.67	82.7	E. G. Zies.
"	32	Tyson.	Mt. Pleasant.	5.75	8.74		48.00	4.37	33.56	100.42	76.7	T. M. Price.
"	33	H. Cramer.	"	9.06	10.92		43.99	0.99	35.65	100.61	78.3	T. M. Price.
"	34	Schley.	Frederick.	.98	.58	.61	34.02	17.11	46.41	99.71	60.6	E. G. Zies.
"	35		"	9.65	2.18	.90	46.42	3.04	38.43	100.62	82.7	Zies & Gill.
"	36	Tabler.	"	2.09	.72		91.48	1.78	4.11	100.18	162.9†	C. F. McKenna.
"	37	M. J. Grove.	"	8.17	2.69	.48	47.27	2.34	38.70	99.65	84.3	E. G. Zies.
"	38	"	"	23.86	.89	.53	36.65	5.10	33.46	100.49	64.8	E. G. Zies.
"	39	"	"	2.47	.77		43.64	9.50	43.97	100.35	77.7	E. G. Zies.
"	40	"	Lime Kiln.	0.85	.72		52.89	1.86	43.30	99.62	58.8	
"	41	"	"	3.76	.88	.50	34.06	15.82	44.09	99.11	60.8	E. G. Zies.
"	42	"	"	3.90	.36		52.23	1.30	42.23	100.02	92.7	H. J. Patterson.
"	43	"	"	0.31	.14		53.35	2.84	44.35	99.99	93.9	H. J. Patterson.
"	44	"	"	3.53	.99	.12	50.70	3.13	42.09	100.56	90.2	E. G. Zies.
"	45	Rogers.	Buckeystown.	0.17	.26		54.98	0.33	43.54	99.28	97.7	
"	46	Keller.	"	4.99	6.28		47.12	1.90	39.09	99.38	83.8	T. M. Price.
"	47	"	"	13.94	1.38	.30	47.02	.66	36.73	100.03	83.2	E. G. Zies.
"	48	"	"	3.08	.95		50.85	2.88	41.81	99.47	90.6	E. G. Zies.
"	49	"	"	6.49	.86	.47	47.40	3.46	40.77	99.45	84.4	E. G. Zies.

* Nos. 1 to 15 refer to analyses of limestones from the Western Piedmont portion of Frederick County, which may be found at the close of the discussion of the Western Piedmont, page 378.

† Burnt lime.

The following table gives the list of limestone operators and producers of lime in this section of the State. It includes the names, not only of the leading operators, but those of a goodly number who only work their quarries intermittently and burn lime occasionally:

LIME AND LIMESTONE OPERATORS IN FREDERICK COUNTY.

FREDERICK AND GLADE VALLEYS.

OPERATOR.	OFFICE.	QUARRY.
Barrick, S. W. & Son	Woodsboro	Woodsboro.
Brookey, Peter	Frederick	Frederick.
Cramer, David	Walkersville	Walkersville.
Crum, John D.	"	Daysville.
Devilbiss, David A.	"	Walkersville.
Eichelberger, Jacob	Woodsboro	Woodsboro.
Fountain Rock Lime Co. (J. W. Stimmel)	Frederick	Fountain Rock.
Frederick Lime and Stone Co.	"	Frederick.
Grove Lime Co., M. J.	Limekiln	Limekiln and Frederick.
Isanogle, A. M.	Thurmont	Catoctin.
Jones, Mordecai	Mt. Pleasant	New London.
Le Gore Lime Co.	Le Gore	Le Gore.
Lewes, R. Rush	Frederick	Frederick.
McAleer, M. Frank	Walkersville	McAleer.
Roddy, F. Daniel	Mt. St. Marys	Motters.
Schley, Gilmer	Frederick	Frederick.
Shinham, D. M.	Hagerstown	Fair View.
Zentz, David G.	Thurmont	Thurmont.
Zimmerman, Wm. C.	Walkersville	Walkersville.

WASHINGTON COUNTY.

Washington County is more generously supplied with raw materials suitable for the manufacture of limes and cements than any other county in the State. It is crossed from northeast to southwest by several belts of limestone, the broadest and most important lying in the eastern section of the county and forming for the most part the floor of the Hagerstown Valley, while the smaller form several detached areas within the Allegheny ranges.

The Hagerstown Valley is underlain by two limestone belts, with an intervening belt of shales. The broader of these belts, covering an area about 15 miles in width, occupies the area between the foot of the Blue Ridge on the east and the Martinsburg shale belt just west of Williamsport on the west. The narrower, covering a territory of from 4 to 5 miles in width, extends from the western margin of the Martinsburg shale belt, above mentioned, on the east, to the foot of North Mountain on the west.

The intervening shale belt has a width of from 2 to 2½ miles. The limestones are admirably adapted to the manufacture of limes and cements, while the shales are excellent as an admixture for the latter. They are of Cambrian and Ordovician age.

In the western part of the county, west of North Mountain, the materials suitable for making lime and cement are less abundant and consist of narrow belts extending across the State. The age of the limestones of this section is Silurian and Lower Devonian, while most of the shales were deposited during the Middle or Upper Devonian.

HAGERSTOWN VALLEY.

The limestones forming the floor of the Hagerstown Valley occupy also the Cumberland Valley to the northeast in Pennsylvania, and the Shenandoah Valley to the southwest in Virginia. All three are but minor divisions of the one great valley that extends from New Jersey southward through Pennsylvania, Maryland, West Virginia, and Virginia, and finally ends in Alabama. These valleys mentioned above are distinguished mainly on the basis of the differences in the direction of their drainage. The waters of the Hagerstown Valley flow southward and empty into the Potomac, while the drainage of the Shenandoah Valley is in the opposite direction into the same river. On the other hand, the Hagerstown Valley is separated from the Cumberland Valley on the northwest by a watershed north of which the streams enter the Susquehanna, and south of which they flow into the Potomac.

Geology.

The Shenandoah limestones of the Hagerstown Valley are in contact on the west with the overlying Martinsburg shale, and on the east with the Harpers shale, since the Antietam sandstone, which normally lies between the limestone and Harpers shale, has been faulted out.

These limestones, composing the Shenandoah group, are blue to light gray in color, and range in composition from almost pure calcium carbonate to calcium carbonate more or less combined with magnesia, silica, alumina, iron, and other impurities. Where the last three are present

in considerable quantity the limestone becomes shaly or argillaceous. The amount of magnesia is rarely sufficient to form a true dolomite, but yet enough is present to make many of the beds valueless for Portland cement manufacture. The limestones also vary in texture from fine-grained to semi-crystalline, and have been found in certain areas of the eastern part of Washington County even as a pure, fine-grained marble.

The recent work of Geo. W. Stose, of the U. S. Geological Survey, has shown that the Shenandoah limestone may be divided into seven independent stratigraphic units. The total thickness of the Shenandoah group, according to his investigations, is about 10,000 feet, or nearly 2 miles.

The following table adapted from Stose* gives the divisions of the Shenandoah group, the overlying Martinsburg formation, and the two formations occurring immediately under the Tomstown, the lowest member of the Shenandoah group. It also gives a correlation with the standard New York section, and although this table refers particularly to the formation comprising the Shenandoah group in southern Pennsylvania, nevertheless it may be used to advantage for our present purposes since, with the possible exception of differences in thickness, it applies to the same divisions as they occur in Maryland:

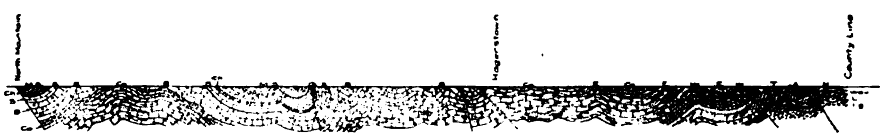
GEOLOGICAL FORMATIONS OF HAGERSTOWN VALLEY.

	Martinsburg formation		Eden, Utica, Upper Trenton	Ordovician.
Shenandoah group	Chambersburg limestone	100-600 feet	Lower Trenton, Black River, Lowville, Upper Chazy	
	Stones River limestone	800-1000 feet	Lower and middle Chazy	
	Beekmantown limestone	2250-2300 feet	Beekmantown	
	Conococheague limestone	1635 ± feet	Saratoga	Cambrian.
	Elbrook formation	3000 ± feet	Acadian	
	Waynesboro formation	1250 ± feet	Georgian	
	Tomstown limestone	1000 ± feet		
	Antietam sandstone			
	Harpers shale			

* Journal of Geology, Vol. XVI, p. 698, 1908.

LIMESTONE FORMATIONS.—Four of the following formations are assigned to the Cambrian and three to the Ordovician, as will be seen by reference to the foregoing table. The thickness and physical characteristics peculiar to each are given below.

The Tomstown (Shady-Sherwood) Formation.—This is a massive drab to white magnesian limestone. Except near the base which is usually concealed the beds comprising this formation are generally impure and high in magnesia. The beds become cherty near the top and pass into alternating beds of sandstone and purple shale. The cherty portion is more resistant to weathering than the rest of the formation, with the result that the major part of the Tomstown formation, as a rule, occupies a valley parallel to the older siliceous rocks on the east



M. Martinsburg shale.	Co. Conococheague l. s.	A. Antietam s. s.
Ch. Chambersburg l. s.	E. Elbrook l. s.	H. Harpers shales.
S. Stones River l. s.	W. Waynesboro s. s. and l. s.	L. Loudon formation.
B. Beekmantown l. s.	T. Tomstown l. s.	Ig. Igneous.
	Wev. Weverton s. s.	

FIG. 22.—Section showing geological structure across Hagerstown Valley (through Hagerstown).

and the cherty ridge composed of the cherty portion of the Tomstown just mentioned. A more prominent ridge, sustained by the siliceous Waynesboro formation, rises, however, near the contact with the Tomstown a little farther west. The latter lies between the Antietam sandstone below and the Waynesboro (Wantaga-Buena Vista) shale above, and has a thickness of about 1000 feet.

The only occurrence of the Tomstown formation in Maryland is confined to the eastern part of Washington County, which it traverses in a general northeast-southwesterly direction. Entering the State from Pennsylvania immediately east of the Waynesboro Branch of the Western Maryland Railroad, it crosses the main line between the stations of Smithsburg and Cavetown, following the foot of the western slope of South Mountain. The area occupied is about 1½ miles wide. The eastern limit of the formation follows the foot of the mountain, while

FIG. 1.—QUARRY OF S. P. ANGLE, HAGERSTOWN.

FIG. 2.—QUARRY OF POTOMAC VALLEY STONE AND LIME COMPANY, PINESBURG.

VIEWS OF HAGERSTOWN VALLEY QUARRIES.

its contact with the overlying Waynesboro follows a line from Cavetown southwestward past Mt. Pleasant to the Washington County Branch of the Baltimore and Ohio Railroad, a short distance west of Keedysville. A roughly parallel line passing a short distance west of Boonesboro and Smithburg describes the boundary on the east. East of a line from Smoketown to Eakles Mills there is infolded a narrow belt of the more resistant ridge-forming Waynesboro. The southern limits of the Tomstown formation are marked by faulting and folding which divides the areal distribution into two narrow areas, one ending south of Eakles Mills, the other faulted a mile more or less north of Tregore Station.

This formation also extends southward to the Potomac near Harpers Ferry, as a small area which has been shifted westward by faulting.

The two chief industrial developments within the limits of the Tomstown formation are widely separated and distinctly different. That at Cavetown is on the Western Maryland Railroad. Here, P. G. Zouck and Company operate a quarry for the manufacture of crushed stone for ballast and for burning to lime. The other operation is at Eakles Mills and is conducted for the quarrying of marble. The white crystalline limestone or marble won here is the result of metamorphism caused by the proximity to and also presence of intense folding and faulting.

The Waynesboro Formation.—The Waynesboro formation, consisting largely of sandstones, purple shales, and hard limestones, yields little or no material for the manufacture of lime and cement, but is serviceable as a maker indicating by its long, low ridges and knobs the areal distribution of the underlying Tomstown and overlying Elbrook formations which form well-defined areas of depression on either side of the Waynesboro elevations.

The formation in Maryland occurs as three narrow belts extending parallel to the mountains in areas more or less enclosed by the adjoining formations. The first of these belts entering the State from the north extends southwesterly from Ringgold past Cavetown and Mt. Pleasant to Keedysville, where it is cut out by a fault. The second area is of slight extent. Beginning about 2 miles east of Smoketown, it forms a low ridge or series of ridges to a point approximately 2 miles northeast of

Eakles Mills. The third area is due to a sharply compressed anticline which brings the Waynesboro formation to the surface in a narrow belt, parallel to the first, extending from 1½ miles east of Mills, past Beaver Creek and Benevola, to a point less than 2 miles east of Sharpsburg.

The formation consists of sandstones, shales, and limestones. Near the base is a siliceous bed of limestone which weathers to a slabby porous sandstone, in the middle are dark-blue to white limestones, rich in magnesia, which grade upward with increase of silica into slabby sandstones and siliceous shales. The thickness, as estimated by Stose, is 1250 feet.

No operations were noted during a field study of this formation, but it is possible that with the development of the cement industry individual beds may be found suitable for mixture with the limestones of the region.

The Elbrook Formation.—The Elbrook formation consists of a series of bluish-gray limestones which are usually shaly or thin-bedded in the weathered outcrop, though appearing massive in the quarry face. Both the more magnesian and the more siliceous beds occur near the center of the formation, while near the top are conglomerate and so-called "edgewise" beds (see Plate XXII) indicative of an unconformity. The thickness of the formation is approximately 3000 feet.

The areal distribution of the Elbrook formation is limited on the east by the low ridges of the Waynesboro formation, and on the west by the relatively rugged topography of the Conococheague formation. The breadth of the area underlain by the Elbrook formation is approximately 2 miles on the Mason and Dixon Line. With this breadth it passes southwestward between Philo and Leitersburg across the Western Maryland Railroad to the Hagerstown-Funkstown electric line, beyond which point it begins to broaden on the west, ultimately merging with a somewhat detached area of the same formation separated by an infolding of the overlying Conococheague. This narrow western belt crosses the Western Maryland Railroad about midway between Bissell and Chewsville, with a breadth of about 1800 feet. South of the union of the two belts, at a point about 1½ miles north of Breathedsville, the area occupied by the Elbrook formation widens to more than 3½ miles in the

vicinity of Sharpsburg. The eastern boundary crosses the Potomac near the westerly bend between Antietam and Dargan. The western boundary, representing the contact between this formation and the overlying Conococheague, crosses the Potomac at Shepherdstown.

No quarries of importance are at present in operation in the Elbrook formation. Suitable beds occur, however, for the manufacture of both lime and cement, although most of the beds are high in magnesia. Pure limestone beds have been located at Chewsville by the Le Gore Lime Company, and property has been purchased there for the opening of a quarry and for the erection of kilns.

During the early days of natural cement manufacture this formation was more extensively worked perhaps than any other one of the Shenandoah group of limestones, as is evidenced by the old, abandoned quarries and mill of the Potomac Natural Cement Company located near the Potomac southwest of Sharpsburg.

The Conococheague Formation.—This formation consists of siliceous and argillaceous limestones which at a number of horizons are suitable for the manufacture of cement. Associated with these are white, drab, or dark magnesian beds. The low ridges marking the position of the base of the formation are due to limestone conglomerates and accompanying siliceous beds. The conglomerate consists of rounded limestone pebbles an inch or more in diameter, imbedded in a calcareous matrix. "Edgewise beds," so called because of their beds being composed of thin fragments of limestone tilted at different angles and held together by calcareous cement, also occur. The unconformable contacts are further marked by oolites and limestones with uneven clay partings. The weathering is also characteristic in that the massive dark-blue limestone which composes the body of the formation on large exposure shows on a gray background brown and yellow bands ranging from an inch in thickness to very thin laminæ. This formation lies between the Elbrook below and the Beekmantown above, and has a thickness of about 1500 feet. It corresponds to the lower part of what was first described by Stose as the Knox limestone.

The Conococheague formation in Washington County occurs both east

and west of the Martinsburg shale belt. The eastern area enters Maryland from the north in a single broad band which, within 3 miles of the boundary, is separated into two areas by the intervening belt of Elbrook already described. The smaller easternmost area of Conococheague extends with an average width of about a mile to a point 1½ miles north of Breathedsville. The larger central area extends southwesterly across the State with an average breadth of a trifle less than 3 miles. The western boundary of this area, except for a small re-entrant south of Hagerstown, may be described as a straight line running from Reid past Hagerstown and St. James to the Potomac River, which it crosses near the boundary between Jefferson and Berkley counties, West Virginia. The eastern limit is the contact with the Elbrook formation already described.

The area of Conococheague west of the Martinsburg shale is about 3000 feet broad on the Pennsylvania boundary, broadening to twice that amount where it is traversed by the Western Maryland Railroad, between Charlton and Big Spring.

Quarries have been opened on the Conococheague formation at a number of points to obtain stone for more or less local consumption, but the most important operation is between Bissell and the Western Maryland Railroad bridge across Antietam Creek. The company operating here is the Security Cement and Lime Company, which is at present increasing the capacity of its Portland cement mill from 800 to 2000 barrels per day.* On account of the character of its materials and the transportation facilities afforded by the Western Maryland, Norfolk and Western, and Baltimore and Ohio Railroads, the Conococheague formation probably gives greater promise of being extensively worked as a source of calcareous material for the manufacture of Portland cement than any of the other members of the Shenandoah group in Washington County.

A large quarry in the Conococheague formation is also operated by S. P. Angle in Hagerstown, northeast of the intersection of the Western

* A detailed description of this plant, the first erected in Maryland for the manufacture of Portland cement will be found on subsequent pages.

Maryland and Cumberland Valley Railroads. Practically the entire output of this plant is sold for railroad ballast, none of the stone quarried being burned into lime.

The Beekmantown Formation.—This formation consists of massive and finely laminated beds characterized by a varying, but usually high, content of magnesia and silica. Pure beds, however, occur, but are more abundant and thicker near the base where they are satisfactory for the manufacture of lime and cement, especially the latter. The horizon near the base marked by the occurrence of "edgewise" and siliceous beds similar to those in the Conococheague, is a transition zone which has been called the "Stonehenge" member. This member has not been represented on the map accompanying this report. The Beekmantown lies between the Conococheague below and the Stones River above, and has a thickness of about 2300 feet.

The Beekmantown formation crosses Washington County in three separate but parallel areas. The widest of the three lies to the east of the Martinsburg shale, while the two narrow belts lie to the west of it.

The largest of the three areas is approximately 4 miles wide, and occupies the territory between Hagerstown on the east and Williamsport on the west. It traverses the State as a broad belt from northeast to southwest, its eastern boundary being marked by its contact with the older Conococheague formation; while on the west the boundary line is the same as that which shows the contact between it and the overlying Stones River formation, except where, as at Williamsport, it is locally in contact with the Chambersburg through faulting.

The two narrower belts west of the Martinsburg shale are separated by the westernmost area of Conococheague. The more eastern of the two underlies the area between Charlton and its contact with the Stones River formation. This line of contact crosses the State in a northeast-southwest direction, and is about 2000 feet west of Pinesburg. The western boundary is marked by the contact with the Conococheague. The width of this area is approximately 1½ miles. The more western of two belts, where traversed by the Western Maryland, is, however, wider than this, but diminishes in width northeastward.

The only quarries of any importance operated on the Beekmantown formation are those worked for the purpose of obtaining road metal, ballast, or stone for use in concrete. Within none of its three belts is the stone quarried and burned into lime, except for supplying a limited local demand. The larger of the two more important plants is located at Halfway, and at present (1909) is not in operation. When worked most of its output went to the Norfolk and Western Railroad for use as ballast. The smaller of the two plants is located on the Williamsport road between Halfway and Hagerstown, and the larger part, if not all, of its output is used in the manufacture of concrete blocks. The absence of lime or cement plants, however, should not be taken to indicate the absence of suitable materials. These occur, but at present are not utilized.

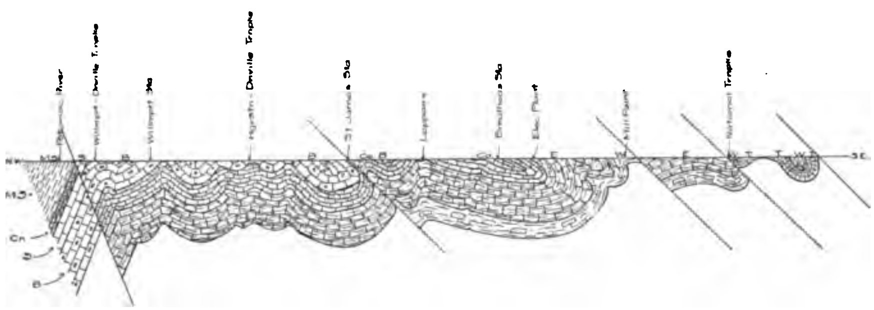
The Stones River Formation.—This consists of very pure dove-colored limestones, together with other beds high in magnesia. The purer beds of limestone occur at and near the top of the formation, and this is the portion which is most extensively quarried. The pure limestone above is followed by equally pure but thinner beds below, alternating with harder beds higher in magnesia. The beds high in lime may be identified where they project above the surface by their weathering into white, smooth, and rounded forms, and may be told by their velvety texture in fresh fracture and by their characteristic dove color. They yield a deep red soil, which is marked usually by a growth of cedars.* "Indeed, the presence of a considerable number of cedar trees in an area of Ordovician strata is quite a reliable sign that the underlying rocks are of Stones River age." Because of this relationship it is sometimes referred to as the "cedar stone."

The Stones River formation lies between the Beekmantown below and the Chambersburg formation above, and usually possesses a thickness of approximately 900 feet.

The areal distribution of the Stones River formation in Washington County is limited to narrow belts closely associated with the broader

* Bassler, R. S. The Cement Resources of Va. west of the Blue Ridge, p. 54.

Martinsburg shale areas. Through faulting the two formations are frequently in contact without the intervening Chambersburg. This faulting has also at times led, as at Williamsport, to a contact of the Chambersburg and Beekmantown without the presence of the Stones River beds. Three belts of Stones River cross the State from Pennsylvania to the Potomac. The first, lying east of the broad Martinsburg shale belt along the Conococheague River, may be described as a narrow band, scarcely ½ mile wide, along the road from Cearfoss to Williamsport. On the east it is limited by the underlying Beekmantown, on the west by a fault which cuts out the overlying Chambersburg, except locally near the



M. S. Martinsburg shale.
Ch. Chambersburg formation.
S. Stones River formation.
B. Beekmantown formation.
Co. Conococheague formation.
E. Elbrook formation.
W. Waynesboro formation.
T. Tomstown formation.

FIG. 23.—Section showing geological structure across Hagerstown Valley (through Boonsboro). (R. C. Williams.)

east end of the stone bridge at Williamsport. The second, lying on the west side of the Martinsburg shales, is here separated from them by a narrow belt of Chambersburg. This second area of Stones River may be described as extending across the State from near Fairview to Pinesburg. The third, lying near the base of North Mountain, likewise extends across the State as a belt from a point just west of Dry Run to the Potomac at McCoys Ferry. This is bounded on the east by the underlying Beekmantown and on the west by a narrow belt of Chambersburg, until the latter is cut out by a fault near Green Spring Furnace. From the latter point to the river this fault is the boundary of the Stones River.

The Chambersburg Formation.—This formation consists of more or less pure argillaceous limestones and calcareous shales. The materials composing it pass from argillaceous limestones at the bottom to calcareous shales at the top. It lies between the Stones River formation below and the Martinsburg shale above. Its range in thickness is from 800 to 1000 feet.

The Chambersburg formation, like the Stones River formation to which in normal position it is superjacent, occurs on both sides of the broad belt of Martinsburg shale. A third belt crosses Washington County in a northeasterly direction from McCoys Ferry on the south, past Fairview, and thence follows the contact with a narrow belt of the Martinsburg shale that lies to the east of North Mountain to a point about ½ mile west of Dry Run on the north. On the east it is in contact with the Stones River formation. The two belts first mentioned lie, respectively, east and west of the broad Martinsburg shale belt which crosses the Potomac at Pinesburg on the west and at Williamsport on the east. The Chambersburg belt to the east is of very limited extent, and only occurs at and in the immediate vicinity of Williamsport. West of the Martinsburg formation the Chambersburg formation is in contact with the former at Pinesburg Station, and is in contact on the west with the Stones River formation. It continues between the contact with the Martinsburg on the east and the Stones River on the west northeastward to the Mason and Dixon Line, continuing thence into Pennsylvania.

The chief value of the Chambersburg formation from an economic viewpoint lies in its argillaceous character and the composition of certain of its beds which are of such a nature that they are almost natural Portland cement mixtures. Suitable mixtures for the manufacture of Portland cement ought to be obtained without difficulty by adding to the material from the "cement beds" of the Chambersburg proper amounts of the pure limestone from the upper portion of the adjoining Stones River formation. So far, however, the Chambersburg formation, though possessing the potentiality just mentioned, has been put to no economic use whatever in Washington County.

FIG. 1.—QUARRY OF THE SECURITY CEMENT AND LIME COMPANY, SECURITY.

FIG. 2.—PLANT OF THE SECURITY CEMENT AND LIME COMPANY, SECURITY.

VIEWS OF PORTLAND CEMENT OPERATIONS, HAGERSTOWN VALLEY.

SHALE FORMATIONS.—The argillaceous material required in the manufacture of Portland cement may be found in the Hagerstown Valley in two geological formations—the Harpers shales, lying beneath and east of the limestones, and the Martinsburg shales, which occur in several belts across the State.

Harpers Shale.—The Harpers shale is exposed on the east side of the Hagerstown Valley in a belt running northeast and southwest, which is ½ to ¾ of a mile wide, and in faulted contact on its west side with the Shenandoah limestone.

The Harpers formation consists of siliceous shales and intercalated beds of sandstone. The shales are bluish-gray in color, weathering to a light greenish-gray. The total thickness, which is not exposed at any one place, is estimated to be about 1200 feet.

Martinsburg Shale.—The Martinsburg shale overlies the Shenandoah limestone and, like the upper part of the Shenandoah group, is Ordovician in age. Three divisions have been distinguished by Stose, which are as follows:

$$\text{Martinsburg formation} \ldots\ldots \begin{cases} \text{Eden.} \\ \text{Utica.} \\ \text{Trenton (upper part).} \end{cases}$$

The Martinsburg formation is composed of thick beds of black and gray shales with thin, interbedded gray to greenish-gray and brownish-colored sandstones. The shales are usually fine-grained in texture and fairly uniform in composition over large areas. At and near the base of the formation they contain lime in amounts varying from about 2 to 10 per cent. The upper beds, however, are lower in lime and higher in silica, which ranges from about 50 to 65 per cent., while the sum of the alumina and iron is generally from 20 to 30 per cent. The thickness of this formation is between 700 and 1000 feet.

Distribution of Lime and Cement Materials in Hagerstown Valley.

CALCAREOUS MATERIALS.—The mineral resources of this region until recently have been little developed, compared with what they might be.

Quarries for limestone to be used locally and for burning into lime have long been operated, but most of the undertakings have been on a small scale. The individual quarries and certain of the more promising opportunities for future development are described in the following pages. These will be discussed according to the railroads which traverse the valley.

Western Maryland Railroad.—Beginning at the eastern end of this railroad, as it crosses the valley, the most important centers of operation are Cavetown, Security, Hagerstown, Williamsport, Pinesburg, and McCoys Ferry.

The quarry at Cavetown is owned and operated by *P. G. Zouck and Company,* who dispose of their product either as crushed stone for ballast or burnt lime for agricultural purposes. This quarry was sampled at two points. Sample No. 1, an analysis of which follows below, was taken to represent the lower 35 feet of the 50-foot breast of stone shown in the quarry:

ANALYSES OF LIMESTONE, P. G. ZOUCK AND CO.'S QUARRY, CAVETOWN.

	No. 1.	No. 2.
Silica (SiO_2)	.79	1.21
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	.94	.54
Lime (CaO)	48.49	50.07
Magnesia (MgO)	5.19	4.85
Ignition	43.95	43.65
Total	99.36	100.32

Near the center of the quarry where the sample, whose composition is given in analysis No. 1, was taken, the 8 to 10 feet of rock capping the rest is a flaggy-white to dove-colored limestone that breaks up on weathering, and when struck with a hammer, into small and more or less cube-shaped blocks. Under this band the limestone is blue to blue-gray and massive. It strikes N. 18° E. and dips 12° E. The total working face is about 50 feet high, but only the bottom 35 feet, as stated above, is represented in the sample.

A second sample of the Zouck Quarry was taken 150 feet west of where the first sample mentioned was obtained. In this sample is included 55 feet of stone, or all of the quarry face, with the exception of several feet of weathered material just under the thin cover of residual soil. The top portion of this 55 feet consists of 18 to 20 feet of dove-colored limestone, below which there is a blue to gray massive bed of limestone extending to the level of the floor of the quarry. The composition of this sample is represented by analysis No. 2.

Both analyses are quite low in clayey matter and high in carbonates so that when burned the stone yields a good quality of lime. Were it not slightly high in magnesia it would be suitable to manufacture into Portland cement.

About ¼ of a mile west of Cavetown, where there is a bridge across the railroad, a number of shaly limestone beds are exposed in the railroad cut for a distance of nearly 200 feet. These strike N. 20° E. and dip about 30° E., and underlie 125 feet of limestone which is blue on fresh fracture, and weathers to a gray to dove-colored surface, and is represented in the sample upon which the analysis below was made:

ANALYSIS (No. 3) OF LIMESTONE ¼ MILE WEST OF CAVETOWN.

Silica (SiO_2)	1.77
Alumina (Al_2O_3)	.73
Iron oxide (Fe_2O_3)	.45
Lime (CaO)	31.80
Magnesia (MgO)	19.51
Ignition	45.69
Total	99.95

At Chewsville there are some old openings in the limestone of the Elbrook formation on property which has recently been acquired by the *Le Gore Lime Company*. Samples were taken on the north side of the railroad 100 feet east of the station (No. 7), and north of the first cut east of the station (No. 8). These samples, on analysis, appeared very satisfactory, as may be seen from the following figures;

ANALYSES (NOS. 7-9) OF LIMESTONE FROM LE GORE PROPERTY, CHEWSVILLE.

	No. 7.	No. 8.	No. 9.
Silica (SiO_2)	1.20	1.10	1.40
Alumina (Al_2O_3), Iron oxide (Fe_2O_3)	1.50	.70	.94
Lime (CaO)	52.30	54.60	54.00
Magnesia (MgO)	2.35	.86	1.15
Ignition	43.56	43.68	43.51
Total	100.91	100.94	101.00

The establishment of a large cement plant at *Security,* a new station situated near the bridge over Antietam Creek about 2 miles east of Hagerstown, has attracted attention to the possibilities of cement manufacture in the State. Before locating at this point the company made careful examinations of many properties throughout the valley. The unusual size of the plant and the fact that it is the first modern Portland cement mill to be erected in Maryland, necessitates a more extended discussion of this area, which will be found under its proper caption on a later page.

The limestone deposits in the immediate vicinity of Hagerstown receive a slight advantage from their proximity to a center of building, but this is largely offset by a corresponding increase in the value of the surface of the land for building purposes, which deters operators from selecting these points for large operations, even when the quantity and quality of the beds are satisfactory.

The central and eastern portions of the city are underlain with limestones of the Conococheague formation, while limestones occurring along the western side of the city are of the Beekmantown formation.

Stone from the Conococheague is quarried by *S. P. Angle* for ballast and road metal.

Promising material conveniently situated with reference to transportation and accessible to suitable shale obtainable from the Martinsburg shale belt west of Williamsport or from the Harpers formation between Edgemont and Smithsburg, is found north of the Agricultural Fair Grounds (Nos. 50-51), Hagerstown, a short distance east of Potomac Avenue Station. Excellent material for the manufacture of cement also

occurs north of and near the junction of the Cumberland Valley and Western Maryland Railroads. Both of these locations have the disadvantage, however, of being rather far removed from water sufficient to supply a cement plant. In order to obtain necessary water for running a large plant the operator would be obliged to convey it by pipe from a pumping station located at some convenient point on Antietam Creek.

The chemical composition of the stone at the latter locality is shown in the following analyses:

ANALYSES OF CONOCOCHEAGUE LIMESTONE, CROSSING C. V. R. R. AND W. MD. R. R., HAGERSTOWN.

	No. 52.	No. 53.	No. 54.	No. 55.	No. 56.
Silica (SiO_2)	7.52	16.04	14.33	4.28	5.51
Alumina (Al_2O_3)	3.05	5.27	4.89	.90	1.80
Iron oxide (Fe_2O_3)	.45	1.25	1.65	.86	.33
Lime (CaO)	48.92	41.30	42.94	52.29	51.85
Magnesia (MgO)	1.76	1.50	2.01	1.52	.32
Ignition	39.11	33.82	34.89	41.06	41.10
Total	100.81	99.81	100.71	100.91	100.91

52. Average of 132 feet below sample 53.
53. Average of 132 feet below sample 54.
54. Average of 132 feet below sample 55 beginning 175 feet N. Switch Tower.
55. Average of 175 feet beginning at Switch Tower.
56. Average of 75 feet west of Switch Tower.

Near Williamsport the juxtaposition of limestones and shales suggests favorable localities for cement manufacture. A sample of the Beekmantown limestone from a point east of the railroad station gave, on analysis, the following results:

ANALYSES OF BEEKMANTOWN LIMESTONE, WILLIAMSPORT.

	No. 67.	No. 68.
Silica (SiO_2)	6.04	4.46
Alumina (Al_2O_3)	1.29	2.13
Iron oxide (Fe_2O_3)	.58	.97
Lime (CaO)	49.68	47.55
Magnesia (MgO)	2.60	2.73
Ignition	40.65	41.44
Total	100.84	99.28

67. Sample taken 630 feet E. of freight station, Williamsport.
68. Average of 350 feet of limestone, Cushwa property E. of station.

Within the thickness represented in the sample on which the analysis above was made, individual beds may occur too high for use on account of their content of magnesia, but they could be located by closer analysis and eliminated in the process of quarrying.

The occurrence together of the raw materials and the favorable situation with respect to transportation by rail or canal render this region especially attractive and worthy of private investigation.

Limestone high in calcium oxide and low in magnesia occurs in contact with the "cement rock" of the Chambersburg formation at Pinesburg. Shale suitable for mixing for the manufacture of cement occurs within a few hundred yards, while an abundant supply of water is afforded by the proximity of this locality to the Potomac. The limestone, although stratigraphically below the purer upper portion of the Stones River formation, contains beds high in lime alternating with beds high in magnesia.

The principal operator at Pinesburg is the *Potomac Valley Stone and Lime Company,* operating two quaries, one for stone to calcine in its kilns and the other for ballast and crushed stone. In the latter quarry the stone, after it is blasted, is loaded into tram cars which carry it to the crusher, where it is broken down into suitable sizes. Most of this crushed stone is sold under contract to the Western Maryland Railroad and is used by the railroad for ballast. The limestone used in the manufacture of lime is from the Stones River formation and is very pure, as shown by the analysis (No. 75) below:

ANALYSES OF LIMESTONE FROM QUARRY OF THE POTOMAC VALLEY STONE AND LIME CO., PINESBURG.

	No. 75.	No. 76.
Silica (SiO_2)	.80	3.10
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	1.20	1.70
Lime (CaO)	53.00	47.25
Magnesia (MgO)	2.06	5.72
Ignition	43.40	43.14
Total	100.46	100.91

PARTIAL ANALYSES OF STONES RIVER LIMESTONE, PINESBURG.

	No. 77.	No. 78.	No. 79.	No. 80.	No. 81.	No. 82.	No. 83.	No. 84.
Silica (SiO_2)*	7.10	2.90	7.66	2.28	6.30	5.42	1.12	1.46
Alumina (Al_2O_3) ...... } Iron oxide (Fe_2O_3) ..... }	.98	1.10	1.04	1.74	1.82	1.60	1.56	1.04
Lime (CaO)	44.44	43.33	40.93	44.26	48.99	45.27	51.70	52.91
Magnesia (MgO)	5.08	8.49	8.55	7.79	1.81	5.65	.69	.80
Ignition	40.25	43.14	41.33	43.09	40.20	41.53	41.09	42.15
Total	97.85	98.96	99.51	99.16	99.12	99.47	96.16	98.36

* Insol.

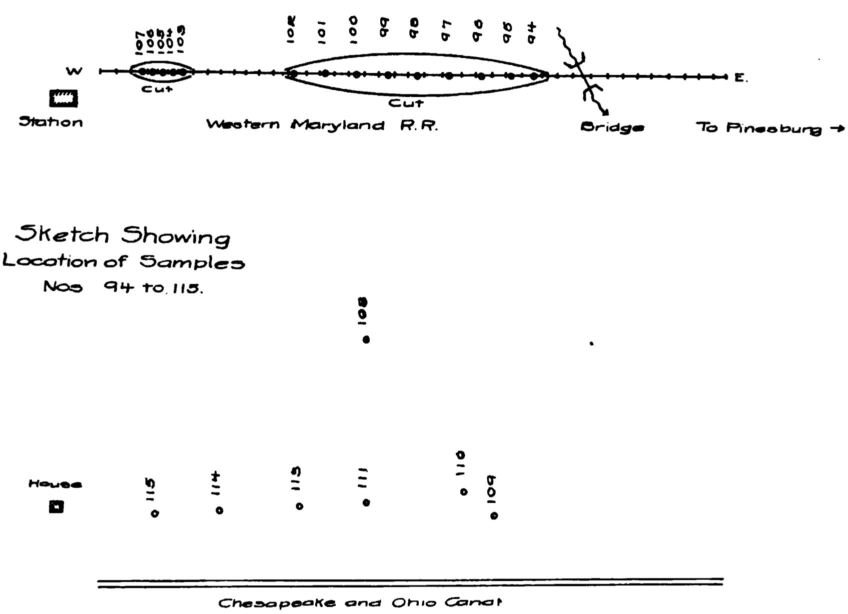


FIG. 24.—Sketch showing location of samples from McComas-Humrichouse farm, near Charlton.

Some of the beds would be satisfactory for Portland cement were they thick enough, while others that are sufficiently thick are too high in their content of magnesia. The same is true to a certain extent of the limestone on the *McComas-Humrichouse* farm, about 1 mile west of Pinesburg Station, where samples Nos. 94-115 were collected. The limestone on and between the McComas-Humrichouse farm and the

Potomac Valley Lime and Stone Company is overlain with a comparatively thin covering of soil, and it is not improbable that more detailed investigation of this area would lead to the discovery of limestone beds suitable for Portland cement, both as regards quantity and quality.

The areal distribution of the samples analyzed is shown in Figure 24, and the results obtained are given in the accompanying table:

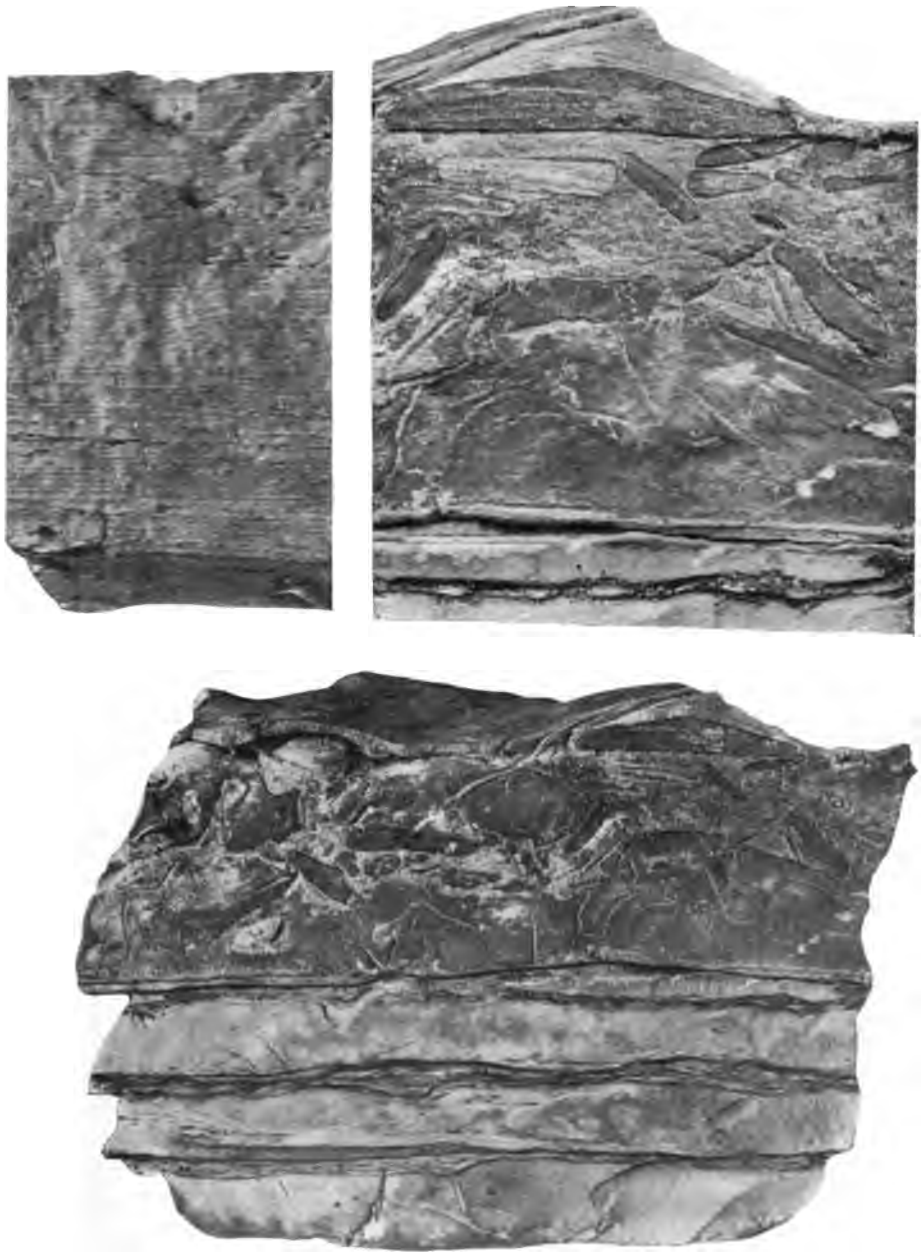
ANALYSES OF BEEKMANTOWN LIMESTONE, NEAR PINESBURG STATION.

Sample No.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron Oxide (Fe_2O_3).	Manganese (MnO).	Lime (CaO).	Magnesia (MgO).	Alkalies (K_2O+Na_2O).	Ignition.	Sulphur.	Water −100°C.	Total.
94	2.86	.28	.28	.04	52.24	2.05	.22	42.08	.03	.06	100.14
95	5.72	.12	.56	.06	51.28	1.01	.48	40.91	.01	.09	100.24
96	4.22	1,64	.28	.09	46.79	5.14	.35	41.50	.01	.02	100.04
97	2.72	.59	.16	.11	53.25	.87	.21	42.10	.03	.04	100.08
98	10.46	2.84	.72	.12	42.06	5.11	1.14	37.27	.11	.03	99.88
99	2.28	1.06	.24	.13	53.19	1.23	.28	41.61	.04	.03	100.04
100	14.17	3.17	1.00	.14	40.32	4.18	1.66	35.37	tr.	.04	100.05
101	4.61	.15	.64	.15	34.53	15.99	.09	44.07	tr.	.03	100.26
102	14.57	4.27	.90	.12	39.07	4.45	1.89	34.39	.09	.03	99.78
103	5.91	1.77	.56	.14	49.56	1.48	.74	39.62	.08	.05	99.91
104	16.20	3.36	.96	.20	39.56	3.44	1.66	34.05	.04	.07	100.04
105	10.62	1.70	1.12	.14	35.16	10.37	2.85	37.98	.07	.14	100.15
106	4.66	.84	.36	.16	51.42	.76	1.14	40.68	.04	.06	100.12
107	3.14	.24	.48	.09	51.94	1.61	.69	41.71	.04	.09	100.03
108	15.98	4.18	1.28	.06	37.50	5.69	1.37	33.89	.05	.17	100.17
109	14.28	2.06	1.20	.23	43.56	2.32	1.22	35.08	.04	.08	100.07
110	2.30	.51	.16	.10	53.06	1.17	.36	42.20	.14	.08	100.06
111	5.66	1.69	.52	.13	50.49	.71	.69	39.85	.10	.10	99.94
113	3.99	1.25	.32	.11	51.99	.65	.61	40.98	.17	.05	100.07
114	3.10	1.11	.32	.12	51.91	.85	.67	41.44	.13	.16	99.81
115	5.76	1.12	.92	—	49.86	.97	1.01	40.30	.12	.08	100.14

Cumberland Valley Railway.—Good material for cement manufacture occurs on the Cumberland Valley Railway near the bridge over the Potomac. The quality of the limestone at this point may be judged by reference to the following analyses:

ANALYSES OF BEEKMANTOWN LIMESTONE, C. V. RY., NEAR WILLIAMSPORT.

	No. 125.	No. 126.	No. 127.	No. 128.	No. 129.
Silica (SiO_2)	6.60	10.80	7.80	4.10	4.00
Alumina (Al_2O_3), Iron oxide (Fe_2O_3)	2.80	2.40	1.40	3.70	3.80
Lime (CaO)	49.50	43.60	49.60	50.20	49.80
Magnesia (MgO)	1.81	4.13	1.55	1.19	1.41
Ignition	40.77	38.68	40.56	40.64	40.57
Total	101.48	99.61	100.91	99.83	99.58



"EDGEWISE BEDS" CHARACTERISTIC OF ELBROOK AND CONOCOCHEAGUE FORMATIONS, HAGERSTOWN VALLEY, WASHINGTON COUNTY.

Shale and an abundant water supply occur near at hand and transportation is afforded by the Cumberland Valley Railway and the Chesapeake and Ohio Canal. The success of a cement plant built here would depend largely on whether suitable arrangements could be made for rates over both the Cumberland Valley and the other railroad lines entering Hagerstown. In many respects this location is an excellent one.

Throughout its course through Maryland the Cumberland Valley Railway, both north and south of Hagerstown, traverses the surface of the Beekmantown formation in which are many beds of pure limestone. The quality of the beds at Hagerstown was given in the foregoing discussion. Little has been done in the way of developing quarries along this railroad because of the lack of favorable quarry sites arising from the interstream position of the railroad in Maryland. South of Williamsport, and near Maugansville are the only points where the line is across streams of any size where the natural trenches offer facilities for a water-free opening with any considerable quarry-face.

Norfolk and Western Railway.—Many excellent occurrences of limestone are found along the line of the Norfolk and Western Railway between Hagerstown and the Norfolk and Western bridge across the Potomac at Shepherdstown. Good exposure occur at many intermediate points.

Limestone beds outcropping on the hillsides near Grimes and Mondell and other small stations where the overburden of soil is insignificant could be quarried to great advantage and at a minimum cost. It is surprising, therefore, that there are not more quarries along this route, but the fact remains that few are in operation, and they are small and operated only intermittently. The chief objection, however, to cement sites along the Norfolk and Western Railway is the distance from a supply of shale, but by employing the proper machinery for preparation and mixing the material the residual soil might be used as a substitute.

Baltimore and Ohio Railroad.—The Washington County Branch, in passing from Hagerstown to Weverton, traverses diagonally the Conococheague and Elbrook formations, and crosses narrow bands of the Waynesboro and Tomstown formations. It is in a limestone area almost

continuously from Hagerstown to Trego. From a short distance north of the latter point to Weverton the country traversed consists of early Cambrian and pre-Cambrian formations. The limestones have been examined from Hagerstown to their contact with the underlying Antietam sandstone.

One of the most favorable localities for development is near Burtner, a flag station on the Baltimore and Ohio Railroad, about 2 miles south of Breathedsville. Here the limestone is well exposed in the hillside on the west of the railroad. Two samples were taken for analysis. The first of these (No. 130) represents beds of limestone aggregating 100 feet, which occur at the north end of the cut near the southern abutments of a trestle. The beds here strike N. 21° E. and dip 53° E. The second (No. 131) represents a thickness, carefully sampled foot by foot, of 150 feet of more or less argillaceous limestone outcropping northeast of the house on the farm owned by Miss Elizabeth Poffenberger. This outcrop is also on the west of the railroad not far from the southern end of the cut represented by the first sample. The analyses below show that the stone is fairly low in magnesia:

ANALYSES OF ELBROOK LIMESTONE, BURTNER STATION, 2 MILES S. BREATHEDSVILLE.

	No. 130.	No. 131.
Silica (SiO_2)	8.71	8.36
Alumina (Al_2O_3)	1.89	2.76
Iron oxide (Fe_2O_3)	.32	.90
Lime (CaO)	45.37	46.42
Magnesia (MgO)	4.67	2.74
Ignition	39.46	39.39
Total	100.42	100.57

A second location apparently favorable for development is that near the bridge over the Antietam Creek. About 50 feet north of the western abutment of the bridge the railroad crosses a road and enters a cut in which the limestone beds are exposed, striking N. 25° E. and dipping 50° E. Sound rock is exposed for over 100 feet. This is followed by

an interval of an equal distance where the rock is too decayed or too heavily covered for satisfactory sampling. A second exposure of solid rock not quite as large as the first succeeds the zone of decay.

Analysis No. 137 represents a composite sample of beds aggregating 100 feet in the first solid portion; analysis No. 136 that of beds aggregating 80 feet from the second portion.

ANALYSES OF ELBROOK LIMESTONE, ANTIETAM CREEK, NEAR KEEDYSVILLE.

	No. 137.	No. 136.
Silica (SiO_2)	15.23	21.98
Alumina (Al_2O_3)	9.21	17.34
Iron oxide (Fe_2O_3)	1.65	2.67
Lime (CaO)	26.53	20.20
Magnesia (MgO)	11.55	4.61
Ignition	35.67	30.89
Total	99.84	97.69

While the four analyses given, especially the latter pair, are higher in magnesia than desirable, the abundance of limestones along the Baltimore and Ohio Railroad suggest the possibility of cement manufacture. The chief disadvantage in locating a plant on this road is the scarcity of good shales. This is not, however, as serious here as on the Norfolk and Western Railway since there is a possibility of using the shales of the Loudon formation which are crossed by the Washington County Branch near Rohrersville. Suitable shale at this horizon is unfortunately poorly exposed.

ARGILLACEOUS MATERIALS.—The argillaceous materials available for mixture with the purer limestones for Portland cement manufacture occur in three general belts. On the east, lying near the western base of the Blue Ridge, are the shales of the Harpers formation, and in the southeast corner of the county, near Rohrersville, shales of the Loudon formation. Both the Loudon and Harpers shales are likely to run too siliceous for this purpose, and to be poorly situated for working. Occasionally these objections are not serious. The following analyses represent an occurrence 660 feet east of a bridge east of Edgemont.

ANALYSES OF HARPERS SHALE, EDGEMONT.

	No. 1.	No. 2.
Silica (SiO_2)	62.80	60.88
Alumina (Al_2O_3)	20.22	20.90
Iron oxide (Fe_2O_3)	6.02	6.63
Lime (CaO)	1.10	1.00
Magnesia (MgO)	2.03	1.81
Ignition	4.00	3.70

Across the center of the valley is a broad belt of Martinsburg shale, the most suitable source of argillaceous components of the cement mixture in the county. Here the shales are fine-grained, relatively free from "quartz," and fairly uniform in composition. The character of these shales is well shown by the following table of analyses of shales from the property of the Security Cement and Lime Company.

ANALYSES OF MARTINSBURG SHALE, SECURITY CEMENT AND LIME CO.'S PROPERTY, 1 MILE E. PINESBURG.

	No. 4.	No. 5.			No. 6.	No. 7.	No. 8.	No. 9.
Silica (SiO_2)	59.20	62.20	63.91	59.74	59.94	59.56	59.44	59.72
Alumina (Al_2O_3) }	25.66	21.25	18.73	22.63	22.87	21.97	22.74	23.04
Iron oxide (Fe_2O_3) }		5.23	8.11	3.16	2.61	3.99	2.34	2.88
Lime (CaO)	3.16	.36	.00	.73	.64	.84	2.00	1.30
Magnesia (MgO)	2.04	.94	1.83	2.43	2.29	2.58	1.87	2.42
Ignition	....	....	7.41	7.73	7.56	7.74	8.94	7.90

The location of plants in the Hagerstown Valley should have an advantage in freight rates over their nearest competitors of the Lehigh district of Pennsylvania and elsewhere outside of the State about sufficient to pay the dividends on their preferred stock. Hence it will be seen that limestone beds of the proper composition are well worth searching for, not only in this part of the State, but in all other sections where the location, quantity and quality of the material make it adapted for use in the manufacture of Portland cement. The recent financial depression has greatly restricted the building of cement plants and has resulted in an unprecedented reduction in the price of the product of operating plants, but, with the return of better conditions, there has been a slow but gradual increase in the price of Portland cement per barrel, and other plants are being built to supply and anticipate the ever-increasing

demand that under normal conditions has characterized the industry during the past 20 years.

*Security Cement and Lime Company.**

The Portland cement plant of the Security Cement and Lime Company is located at Security, a new station on the Western Maryland Railroad about 2 miles east of Hagerstown. It was completed and put in operation with its present capacity of 800 barrels a day during the summer of 1908. The plant was constructed by the Maryland Portland Cement Company, which combined in the fall of 1909 with the Berkeley Lime Company of West Virginia to form the present corporation. This new company is now increasing the capacity of the present plant so that when the enlarged plant is completed the daily capacity will amount to about 2400 barrels a day.

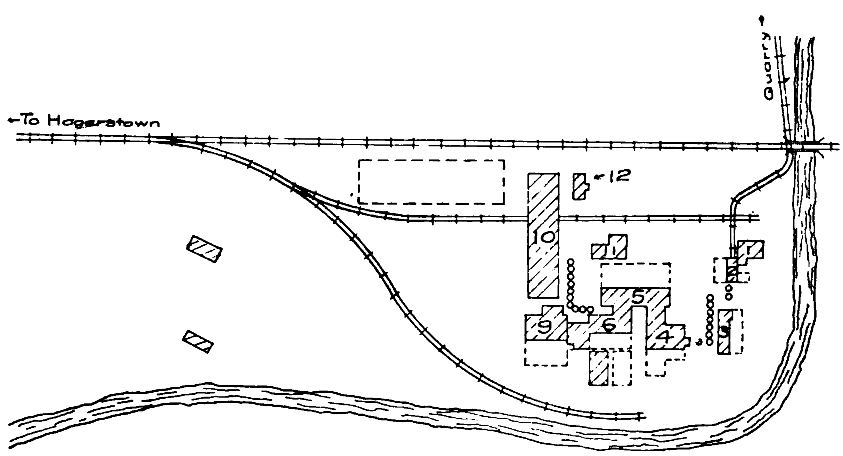
The raw materials of the Security Cement and Lime Company are limestone and shale. The company owns 131 acres of limestone land at Security, and a shale quarry near Pinesburg, some 10 miles distant. The cement mill is located on the limestone property and is built on the opposite side of the railroad from the quarry. The latter is opened on a natural quarry face 40 to 45 feet in height, situated on the east bank of Antietam Creek, and about 700 feet up the stream from the site of the plant. The stone from the quarry is conveyed to the crusher in cars traveling on a tram track paralleling the creek and passing under the bridge of the Western Maryland Railroad.

The limestone on this property varies in composition with different beds, but is uniformly low in the content of magnesia. Excepting a few thin beds in no case has the magnesia been found to exceed 3 per cent., and it is usually much below this, as may be observed from the table of analyses. Analyses 31-48 give the composition of the beds exposed along the railroad track at points 31 and 48 of the map, and of the beds that outcrop between these two points. Likewise analyses 16-23 and 24-30 give the composition of the beds at these and intermediate points at and

* Date furnished by J. S. Grasty.

in the vicinity of the quarry. The limestones on which these analyses were made vary in texture and composition, some being fine-grained, medium, hard, and blue and gray on fresh fracture, weathering to a light gray to dove color; others being more argillaceous weathering to a rough corrugated and banded surface. Both varieties are members of the Conococheague formation.

Owing to the manner in which the limestone has been folded here, the beds outcropping on the east side of the property are exposed near the center, and again near the western boundary. They strike N. 10° to



1. Crusher. 2. Drier. 3. Grinder. 4. Mixing mill. 5. Kilns. 6. Driers. 9. Clinker mill. 10. Warehouse. 11. Coal mill. 12. Laboratory.

FIG. 25.—Plan of arrangement of buildings of Security Cement and Lime Company, Security.

15° E., and at the quarry dip 70° E. The axis of one anticline follows the direction (N. 10° to 20° E.) of the low ridge cut by the railroad between the station and the bridge, and the other, parallel to the first, crosses the railroad about 600 feet west of where the spur track to the plant turns off from the main line, or about 700 feet east of the company's station.

Antietam Creek, where it flows past the quarry, has cut into the flank of the first of the two anticlines mentioned above, and as a result has produced the natural quarry face already referred to. A synclinal fold

passes, as must be obvious from the foregoing, near the center of the property in a direction N. 10° to 15° E., and parallels the low ridge northeast of the station.

The following analyses of limestones and shale may be considered as typical of the composition of these materials on this company's two properties:

ANALYSES OF RAW MATERIALS USED BY SECURITY CEMENT AND LIME CO.

	Limestones			Shale		
		24.	28.			5.
Silica (SiO_2)	7.06	6.04	5.62	62.60	63.91	59.74
Alumina (Al_2O_3)	1.08	1.96	1.21	21.25	18.73	22.63
Iron oxide (Fe_2O_3)	1.01	.62	.81	5.23	8.11	3.16
Lime (CaO)	49.14	48.88	49.78	.36	none	.73
Magnesia (MgO)	1.70	1.74	1.58	.94	1.83	2.43
Ignition	40.02	39.30	40.96	....	7.41	7.73

It will be observed that besides the constituents being properly proportioned both in the limestone and shale each is very low in magnesia, while the former is quite high in its content of clayey matter.

Before the limestone and shale properties were purchased large samples of these materials were procured and shipped to well-known commercial chemists, Booth, Garrett and Blair, of Philadelphia, where, in their laboratory, it was made into Portland cement. The product was then tested, and the results obtained were satisfactory in every particular.

As was shown in the section on the calculation of cement mixtures, where two of the above analyses were used, only about 1 part by weight of shale is required here for 6 parts by weight of limestone. The amount of shale entering the mixture is thus seen to be relatively small because of the argillaceous content of the limestone. This is regarded as a great advantage in view of the fact that the shale must be hauled from a separate quarry.

The Security Cement and Lime Company is supplied with sufficient raw material to run its plant with its contemplated capacity of 2000 barrels a day for a very long period of years. Water, which is used in greater quantity by weight than any other raw material in cement manufacture, also exists in abundant supply on the company's property.

	Fineness % passing.			Setting time. Initial.		Final.		Comp. of Pat. Parts of			Harden'g time, days.			Tensile strength.	Specific gravity.	Chemical composition.					
	50	100	200	h.	m.	h.	m.	Cement.	Sand.	% Water.	Air.	Water.	Total.			SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Alk.
I.			80.0	2	0	4	15	1	0	21	1	0	1	368	....	23.11	5.89	2.80	61.53	2.21	1.56
								1	0	21	1	6	7	779							
								1	0	21	1	27	28	870							
								1	0	21	1	88	89	918							
								1	3	8	1	6	7	366							
								1	3	8	1	27	28	435							
								1	3	8	1	88	89	480							
II.		93		3	0	5	30	1	0				1	204	3.2	....	....	....	....	2.88	1.16
								1	0				7	514							
								1	0				28	698							
								1	3				7	189							
								1	3				28	268							
III.		95.8	77.0	1	25	3	40	1	0	21	1	0	1	385	....	23.04	5.81	2.41	61.38	1.61	1.60*
								1	0	21	1	90	91	765							
								1	0	21	1	6	7	776							
								1	0	21	1	27	28	831							
								1	3	9	1	6	7	255							
								1	3	9	1	27	28	387							
								1	3	9	1	90	91	426							
IV.		97.2	95.2	2	32	6	41	1	0	20			1	440	....	23.10	7.08	1.84	62.25	1.97	1.70†
								1	0	20			7	787							
								1	0	20			28	833							
								1	3	10			7	329							
													28	454							
V.	99	98.8	96.46	1	22	5	15				1	1	2	329	3.107	23.82	5.82	2.70	62.87	2.18	1.18‡
											1	6	7	727							

* Ignition 2.38.
† " 2.06.
‡ " .56.

I. Tested by Booth, Garrett and Blair.
II. " B. F. Fendall.
III. " H. S. Spackman Eng. Co.
IV. " Osborn Eng. Co.
V. " H. C. Deming.

Below will be found the analysis of the cement actually made from the raw materials whose composition was given above. Along with the analysis an average analysis of seven other leading cement brands is submitted for comparison:

ANALYSES OF PORTLAND CEMENT.

	Analysis of Security Cement and Lime Co. brand.	Average analysis of 7 other established brands.
Silica (SiO_2)	21.72*	21.86†
Alumina (Al_2O_3)	7.66	7.19
Iron oxide (Fe_2O_3)	2.50	2.99
Lime (CaO)	62.91	62.42
Magnesia (MgO)	2.30	2.58
Sulphur dioxide (SO_2)	1.48	1.48
Total	98.57	98.52

* The analyses obtained in 1908 show higher content of silica with corresponding slower set and greater ultimate strength. This is due to the use of a slightly more siliceous limestone than that used in the calculations.

† Bull. No. 331, U. S. Geological Survey.

From the above analyses it is evident that the Security Cement and Lime Company is manufacturing a cement that is of the same composition as the best brands and, therefore, should, on its merit, be abundantly able to compete with these in the market.

The plant at Security is well located. The cement markets of Washington and Baltimore are near at hand, while five railroads center 2 miles from the plant at Hagerstown, and reach large sections of the States of Pennsylvania, Maryland, Virginia, and West Virginia. With a plant having five times the contemplated capacity of the one now building, this company would still be unable to supply the demand of the market which its strategic position ought to give it and other plants yet to be erected in Maryland.

In all Portland cement plants the work of machines is hard and continuous, and the wear and tear of machinery is unusually high. This is particularly true of machinery for clinker-grinding, and it may be readily imagined that the grinding of a close-grained and compact limestone, like that at Security is by no means an easy mechanical process.

A most important point in a cement plant, therefore, is to subdivide the process as skilfully as possible so that in case of a stoppage for repairs or adjustment of machinery at any point, or from any cause, the working of the plant as a whole will be interfered with as little as possible. It is important that the effect of these minor repairs of adjustments should be confined within narrow limits. For example: A belt may be slipping and need to be cut; a driving chain may come off a sprocket; an elevator or conveyor may choke at some point; a score of minor difficulties like these may occur from time to time. If the plant is so constructed that such repairs or adjustments would stop not only the features in question but make it necessary to stop a considerable number of other machines or any considerable part of the plant, the whole output of the factory would be curtailed to just that extent.

In designing the plant at Security, therefore, the purpose has been to have at every point machines with ample capacity, able to do considerably more than is regularly required of them. Then the power has been subdivided so that any machine or group of machines may be cut out without stopping the operation of any considerable amount of adjacent machinery. To supplement this and render it practically effective, large bin and storage facilities have been provided throughout the plant so that mills and kilns can continue in operation during all minor repairs.

The plant has also been designed so that all machines which must operate together in carrying out any part of the process are driven from the same power. This feature has very frequently been overlooked in cement plants. Elevators are driven from one line of shafting while the conveyor delivering to them is driven from another line of shafting. If either source of power stops the conveying system is out of commission. This is a very common error, and the essential cause for lack of efficiency in many plants. It is a little more trouble to carry power from one building to an adjacent building merely to reach an elevator, which nevertheless it is very important to do, as the stoppage of this elevator driven by some other source of power would stop the mills which preceded it.

In first cost, and also in operating cost, while running, the plant at Security, which is at present a comparatively small unit, would, no doubt, be most economically served by one large Corliss engine. But if this engine had to stop for all minor repairs and the whole plant stopped with the engine, it would be a most expensive installation by reason of loss of output and efficiency in the plant as a whole. Hence, for the purpose of differentiating the power and keeping all parts of the plant in operation continuously, and as far as possible independently of any localized delays or repairs, the Security plant has six engines and ten electric motors, connected up so that the particular processes which each has to deal with are not only independent of other processes but will be completely carried out from one source of power. In its other features it has the best machinery available on the market for the purposes in view, and as a complete plant unit it should have an unusual output. The general plans are for a plant having a capacity of 2500 barrels per day. The present installation is for 800 barrels per day, everything being placed in position for the larger unit.

The raw materials are mixed by weight as they come from the quarry, and this mixture of raw materials passes through the first process of reduction, which is a gyratory crusher. The raw material is then dried and afterwards ground by gradual reduction through suitable machines. There are large storage tanks between the crusher and the dryer and between the dryer and the rock mill. Moreover, there are large storage bins in the mills and in the kiln building. The kilns are 7 feet in diameter and within a few inches of 100 feet in length, each with a working capacity of about 400 barrels per day. Each kiln is supplied with a clinker cooler. There are also large storage tanks for clinker between the clinker coolers and the cement mill, and in connection with the latter bin capacity is provided of ample proportions.

The stock house has a cellular system of bins for storage and sampling of different lots of cement.

The company has two long trestles affording ample storage and cheap handling for coal, both for boiler and kiln purposes, and also for shale.

Natural Cement Operations.

Natural cement was formerly made in Washington County by the Potomac Cement Company, of Antietam, Maryland, and when mentioned, the mill or company, as the case may be, is usually referred to as the Antietam Cement Plant or Company. The mill, however, is not situated at the town of Antietam or on Antietam Creek, but on the Chesapeake and Ohio Canal a mile or more down stream from the bridge spanning the Potomac at Shepherdstown, West Virginia. The plant was started in 1888 by William H. Blackford and some Baltimore capitalists. It was built with a capacity of 300 barrels per day, but the average output according to available reports was about 200 barrels. Later the plant and property were sold to Washington parties, who now own them. They ceased operations in 1903. It is understood that it was never a financial success. At present the plant is in a very dilapidated condition, the retaining walls of the kilns having fallen away on one side.

ANALYSES OF LIMESTONE FOR NATURAL CEMENT, SHEPHERDSTOWN, W. VA.

	1 Rock used.	2 Green Rock.	3 Gillmore Analysis.
Silica (SiO_2)	15.89	43.67	17.84
Alumina (Al_2O_3)	5.58	11.55	4.60
Iron oxide (Fe_2O_3)	.74	.38	1.70
Iron oxide (FeO)	1.00	2.91	....
Lime carbonate ($CaCO_3$)	52.74	16.73	58.25
Magnesium carbonate ($MgCO_3$)	19.06	21.99	11.16
Alkalies ($Na_2O + K_2O$)	4.92	2.61	3.26
Sulphur (SO_3)	.31	0.00	.74
Phosphorus (P_2O_5)	.12	.19	....
Titanium (TiO_2)	....	.48	....

From the site of this mill may be seen, across the Potomac on the West Virginia side, the old mill of the Shepherdstown Cement Company, which is located about 1 mile east of Shepherdstown. The latter has not been in operation since 1900. Both mills based their operation on the use of an argillaceous and highly magnesian limestone having at both places about the same range in chemical composition. The above analysis made by the West Virginia Geological Survey is fairly indicative of the composition of the same beds of Cambro-Ordovician limestone

burned by the Maryland plant operating on beds of similar material that strike across the river and formerly were worked where the samples whose analyses are submitted above were taken.

The "green rock," whose composition is given in analysis No. 2, is so called by the quarrymen because of its characteristic color. According to Grimsley * it burns to a hard clinker and is not used on this account. Analysis No. 3 above is quoted from Gillmore † by Grimsley.

The Maryland mill and the West Virginia plant across the river produced cement of practically the same composition. The following analysis will, therefore, suffice to show about the average composition of both.

ANALYSIS OF NATURAL CEMENT, ANTIETAM.*

	Per cent.
Silica (SiO_2)	26.65
Alumina (Al_2O_3)	12.38
Iron oxide (Fe_2O_3)	2.14
Lime (CaO)	33.20
Magnesia (MgO)	12.56

* Mineral Industry, Vol. VI, p. 96.

The limestone is well exposed on both sides of the river. On the West Virginia side it rises to an elevation of about 125 feet, is little covered by residual soil, and could again be worked at moderate cost by the methods of quarrying by open cut, as was done on both sides of the river when these two cement mills were in operation. It is exposed for over a mile with beds of varying composition. The impurer beds of limestone are too high in magnesia to be used for Portland cement, but they could be neglected, while the purer beds might be worked to advantage. The residual soils a little distance back from the river could be obtained and employed to supply the argillaceous portion of the mixture, or Martinsburg shale might be had by a shipment of a distance of 12 miles by canal or Harpers shale on the Maryland side by shipping about a third as far. Suitable coal could doubtless be obtained at reduced cost by shipment by canal, which would furnish transportation by water to Washington for the finished product, and the facilities afforded

* Grimsley, G. P. W. Va. Geological Survey, Vol. III, p. 500.

† Limes, Hydraulic Cements and Mortars, 1872.

by the Norfolk and Western less than a mile away for rail transportation could also be utilized. To those interested in locating sites for Portland cement plants further investigation of the materials occurring in this vicinity might prove to be well worth both the expense and time spent.

WESTERN WASHINGTON COUNTY.

Geology.

The calcareous materials of the western part of Washington County are obtained from two formations, namely, the Cayuga and the Helderberg. The points where they may be worked at present, on other than a very small scale because of absence of transportation facilities, are confined to the outcrops on or near the Western Maryland Railroad. The younger of these two limestone formations, the Helderberg, is overlain by great masses of Devonian shale. The order of succession of these formations from top to bottom is

Devonian shale,
Helderberg limestone,
Cayuga limestone.

As the result of the movements which occurred at the close of the Carboniferous age, these formations and those that occupy positions either stratigraphically above or below them, were uplifted and folded into broad synclines and anticlines slightly overturned westward. Minor flexures are superposed upon these folds, resulting in the characteristic "Appalachian structure." The folds cross the State in a northeast-southwest direction, as may be seen from the geological map of the State.

CALCAREOUS MATERIALS.—The *Cayuga formation* is Silurian in age and lies between the older Niagara formation and the younger Helderberg. In Washington County it occurs in several areas from North Mountain westward, but has only been worked west of Hancock where certain of its beds have been mined and manufactured into natural cement. It may be divided into the following lithological units:

Thin-bedded and massive limestones at the top.

Shaly limestones and greenish shale.

Red sandstones and shale.

Drab shale and thin, interbedded limestones at the bottom.

The total thickness of the Cayuga is 1500 to 1600 feet. Two divisions have been recognized hitherto in the strata overlying the drab shales. The uppermost division, comprising about 110 feet, has been termed the Manlius member, while the strata underlying the latter and overlying the drab shales have been termed the Salina member. This division is based wholly upon the contained fossils and cannot be recognized by any differences in the character of the rocks. It will, therefore, not be discussed further at this place.

The drab shales forming the base of the Cayuga contains some calcareous beds but they are not important.

The strata overlying the red sandstones contain four cement beds, some of which have been extensively worked for the manufacture of cement, rendering the Cayuga formation of much commercial importance. It is well exposed at the works of the Round Top Hydraulic Cement Company, a few miles west of Hancock, on the Western Maryland Railroad, and also at another point on the same railroad a few hundred feet east of Dam No. 6 on the Potomac. The following analysis submitted below is furnished by Mr. Austin L. Gallagher, Industrial Agent of the Western Maryland Railroad, who had it made on a sample of limestone taken from the Tonoloway quarries near Dam No. 6:

ANALYSIS OF CAYUGA LIMESTONE, TONOLOWAY QUARRIES, DAM No. 6, WEST OF HANCOCK.

Silica (SiO_2)	14.06
Alumina (Al_2O_3)	2.15
Iron oxide (Fe_2O_3)	.32
Carbonate of lime ($CaCO_3$)	79.85
Carbonate of magnesia ($MgCO_3$)	3.54
Organic	.08
Total	100.00

Helderberg Formation.—The Helderberg limestone occurs at the base of the Devonian and the other formations of that system, being composed entirely of shales and thin-bedded sandstones. Some geologists refer the Helderberg to the top of the Silurian. It is exposed in Wash-

ington County on the Western Maryland Railroad, west of North Mountain, west of Hancock and east of Dam No. 6 on the Potomac. These points of outcrop are shown on the accompanying map.

The Helderberg consists of about 260 feet of beds of pure magnesian and argillaceous limestones, together with cherty limestone strata and a few beds of shale. Three divisions are recognized, known as the Coeymans, New Scotland, and Becraft members.

The *Coeymans* consists of heavy-bedded limestones usually very fossiliferous and with some cherty beds near its base. Among its fossils are very large *Stromatopora,* which weather into curly, nodular masses. The thickness of this member, which is the lowest one of the three, is about 110 feet.

The *New Scotland* or middle member of the Helderberg consists of massive beds of gray limestone with bands and stringers of chert. In some localities these massive beds of limestone become shaly and argillaceous owing to differences in the conditions of deposition under which they were originally formed. The thickness of this member is about 60 feet.

The Becraft, which is the top member of the Helderberg, consists of blue to gray limestones. Some of the beds toward the top are extremely cherty. The longer direction of the chert nodules, which vary in size, are arranged in parallel direction and occur as continuous and broken bands or ridges parallel to the bedding. Their greater resistance to erosion than the limestone in which they are imbedded results in their standing out against the limestone surface in parallel and more or less broken ridges.

ARGILLACEOUS MATERIALS.—The argillaceous materials of the western part of Washington County suitable for use in Portland cement mixtures are obtainable chiefly from the shales of Devonian age which overlie the calcareous materials. The shales are found in the following formations:

Jennings	Chemung. Portage. Genesee.
Romney	Hamilton. Marcellus.

FIG. 1.—VIEW OF FOLDED STRATA, ROUND TOP, NEAR HANCOCK.

FIG. 2.—OLD NATURAL CEMENT PLANT, ROUND TOP, NEAR HANCOCK.

VIEWS OF NATURAL CEMENT OPERATIONS, WESTERN WASHINGTON COUNTY.

Romney Formation.—The Romney formation overlies the Helderberg and occupies the middle section of the Devonian. It ranges from 1600 feet in thickness in Washington County to 500 and 600 feet beyond Wills Mountain, near Cumberland. This formation is divided into two members, the Marcellus member and the Hamilton member.

The *Marcellus* is the lower member of the Romney; in thickness it is about one-third that of the Romney. It consists of thin, black, papery, carbonaceous shales possessing marked fissility and easily crumpled between the fingers. Occasional thin beds of limestone occur in the higher portions of the formation some distance above its base. The Marcellus is easily eroded, and hence occupies the valleys and sides of valleys wherever it occurs in Maryland.

The *Hamilton* is the upper and thicker of the two members of the Romney. Its thickness is about two-thirds that of the entire Romney formation. It consists of green to greenish-black or brown shales and sandstones. Two heavy sandstone beds occur in it, one of which is found near the middle of the Hamilton. They stand out from the softer material and form noticeable topographic features. The Hamilton shales are inclined to be arenaceous. On weathering their dark color is lost and they become yellow and brown. This is particularly true of the upper part of this division, where the shales are also characterized by their tendency to break into irregular fragments. The lower part of the formation is difficult to distinguish from the upper section of the Marcellus, from which it is separated, on evidence furnished by fossils rather than by lithological differences.

The Upper Devonian comprises two divisions, the Jennings and the Hampshire formations, respectively. The former includes 4000 feet from bottom up, and the latter the next succeeding 2000 feet.

Jennings Formation.—The Jennings formation is divided into three members. The order of superposition from top to bottom is as follows:

Chemung.
Portage.
Genesee.

The *Genesee* consists of black fissile, argillaceous shales that weather to flat, dark plates and exhibit marked jointing like that seen in the

same formation in New York. This formation is absent in Washington County, but occurs further west in Allegany at the base of the Jennings.

The *Portage* is the middle member of the Jennings. It is composed of alternating shales and thinner sandstones and conglomerates interbedded with shales in the upper portion. The shales toward the base are usually argillaceous and fissile, becoming at higher horizons more arenaceous or sandy and olive-green in color. They weather into thin, flat plates, easily distinguished from the softer and hackly fractured fragments of the underlying Romney. The Portage is about 2000 feet thick and is connected by beds of passage with the overlying Chemung member.

The *Chemung* member of the Jennings formation overlies the Portage and occurs immediately below the Hampshire formation. It consists of sandstone, conglomerates and arenaceous shales. It contains several beds of conglomerates. The resistant character of these conglomerates results in their standing out as more or less prominent topographic forms. The thickness of the Chemung ranges from 1700 to 1800 feet.

Distribution of Lime and Cement Materials in Western Washington County.

The total thickness of the limestone formations in the western part of Washington County is nearly 1400 feet, while that of the shale reaches the enormous total of over a mile. Most of the calcareous material, however, is unsuited for making either lime or cement, though the greater part of the shale is of a composition such that with suitable deposits of limestone it could be readily utilized in a mixture for the manufacture of Portland cement. The only places in the western part of Washington County worth considering as locations for lime kilns to supply other than a local demand, or for cement plants, is where limestone in the former case and limestone and shale in the latter case outcrop along the Western Maryland Railroad, the only transportation route in this part of the county. The following are the several points that have been examined, the Cayuga, at Hancock and near the works of the Round Top Natural Cement Company, and some of the calcareous and

argillaceous material at Tonoloway Station on the Western Maryland Railroads, across the river from Great Cacapon, West Virginia.

HANCOCK DISTRICT.—The upper part of the Cayuga is quarried just beyond the western limits of Hancock, on the Warfordsburg Road, at locality No. 116 of the map. The small quarry sampled at this point is known as the Whitmeyer-Bridges Quarry. On fresh fracture the limestone exposed here is blue, weathering to a dove-gray color on the surface. Shaly limestone overlies and underlies the 50 feet of blue-gray massive limestone represented in the sample. This quarry is opened on the east side of the road going north. An analysis of the sample selected by the writers gave the following:

ANALYSIS OF CAYUGA LIMESTONE, WHITMEYER-BRIDGES QUARRY, HANCOCK.

	No. 116.
Silica (SiO_2)	5.65
Alumina (Al_2O_3)	2.57
Iron oxide (Fe_2O_3)	.68
Lime (CaO)	50.48
Magnesia (MgO)	.76
Ignition	40.17
Total	100.41

The composition of this material, as shown by the above analysis, indicates that it would be suitable to manufacture with shale into Portland cement. At present it is burned into lime.

A great thickness of Cayuga limestone is exposed both to the east and west, especially in the latter direction, from the closed plant of the Round Top Natural Cement Company. When this company was working, material was obtained by mining the four natural cement beds west of the plant. A sample was taken of the second bed west of the plant. This bed, which is a blue, argillaceous limestone, has a thickness of 12 feet. If other material of sufficient quantity and of the same composition could be found here, which is not at all improbable, it might result in the conversion of the abandoned works into a plant manufacturing Portland cement, since the analysis that follows shows that the material collected is a "cement rock" closely analogous in composition to those of Trenton age of the Lehigh district.

ANALYSIS OF CAYUGA LIMESTONE, SECOND CEMENT BED, ROUND TOP NATURAL CEMENT CO., HANCOCK.

	(No. 121.)
Silica (SiO_2)	20.16
Alumina (Al_2O_3)	6.34
Iron oxide (Fe_2O_3)	1.36
Lime (CaO)	38.56
Magnesia (MgO)	2.07
Ignition	31.74
Total	100.23

This cement rock, if a more detailed investigation should disclose it to be in greater quantity than it was found in the preliminary examination, might be used to make a suitable Portland cement mixture with limestone of the upper part of the Cayuga having the composition given above. Very little, however, of the latter would be required.

The works of the Round Top Natural Cement Company are situated between the railroad and canal. The plant was destroyed by fire in 1903. but was again rebuilt, with a capacity of about 300 barrels a day. The first cement in this district was made at this point in 1837.

TONOLOWAY DISTRICT.—Samples of Helderberg limestone and Devonian shale were taken at Tonoloway Station, which is at Dam No. 6 of the Potomac. Analysis shows that all of the material sampled there would be suitable to enter into a Portland cement mixture. The point where these samples were taken is indicated by the numerals 122 on the accompanying map.

Sample No. 122 represents 198.5 feet of Helderberg limestone. It includes the massive and highly fossiliferous crinoidal beds of the Helderberg and the adjoining 24 feet of the Cayuga. The beds dip 50° W. and strike N. 25° E. Sampling was begun 496 feet east of the railroad watch-house, which is 25 to 30 feet from Lock House No. 6, and includes the limestone between this point and a point 198½ feet farther west. The analysis below shows that this material is truly a "cement rock" which could be burned into Portland cement with the admixture of a very small quantity of pure limestone. A second analysis made on a sample taken from the upper part of the Helderberg indicates that this part of the formation is high in magnesia.

ANALYSIS 1, HELDERBERG LIMESTONE, "CEMENT ROCK," TONOLOWAY OR DAM No. 6.

	No. 122.
Silica (SiO_2)	21.72
Alumina (Al_2O_3)	5.88
Iron oxide (Fe_2O_3)	1.85
Lime (CaO)	36.91
Magnesia (MgO)	2.10
Ignition	30.91
Total	99.37

A sample of the black carbonaceous Romney shale representing 214 feet of material from beds dipping 80° W. was taken between the points 198 feet and 412 feet west of the west abutment of the bridge of the Western Maryland Railroad across Tonoloway Creek. The analysis follows below:

PARTIAL ANALYSIS OF ROMNEY SHALE, TONOLOWAY CREEK.

	No. 15.
Silica (SiO_2)	68.03
Alumina (Al_2O_3)	14.65
Iron oxide (Fe_2O_3)	6.17
Lime (CaO)	1.28
Magnesia (MgO)	.50
Ignition	4.24
Total	94.87

The Jennings formation outcrops west of Tonoloway Creek in contact with the underlying Romney. A sample was selected which consisted of olive-green and gray shales possessing rather marked fissility, but breaking into fragments with rough, hackly edges. It included 66 feet of material between the distances 1158 and 1224 feet west of Tonoloway Creek. The following is the analysis which, like that of the Romney given above, shows a composition satisfactory for mixing with limestone in the manufacture of Portland cement:

ANALYSIS OF JENNINGS SHALE, TONOLOWAY.

	No. 16.
Silica (SiO_2)	65.65
Alumina (Al_2O_3)	18.70
Iron oxide (Fe_2O_3)	5.91
Lime (CaO)	.65
Magnesia (MgO)	1.41
Ignition	5.16
Total	97.48

WASHINGTON COUNTY.

LIMESTONE.

Map No.	Name of limestone.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3)	Iron (Fe_2O_3)	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
½	Tomstown.		Leitersburg.	4.08	4.70		45.94	4.64	41.61	100.52	81.7	T. M. Price.
1	"	Zouck.	Cavetown.	.79	.94		48.49	5.19	43.95	99.86	86.4	E. G. Zies.
2	"	"	"	1.21	.54		50.07	4.85	43.65	100.32	89.1	E. G. Zies.
3	"		"	1.77	.73	.45	31.30	19.51	45.69	99.95	57.0	E. G. Zies.
4	"	Zouck.	"	0.74	6.98		50.97	0.85	40.43	99.47	90.6	T. M. Price.
5	"	"	"	12.00	4.42		46.54	0.44	36.78	100.18	82.8	T. M. Price.
6	"	"	"	11.18	8.00		44.03	1.24	35.70	100.10	78.8	T. M. Price.
7	Elbrook.	Le Gore.	Chewsville.	1.20	1.50		52.80	2.85	43.56	100.91	93.0	T. M. Price.
8	"	"	"	1.10	.70		54.60	.86	43.68	100.94	97.0	R. S. Williamson.
9	"	"	"	1.40	.94		.54	1.15	43.51	101.00	0.96	R. S. Williamson.
10	"	.	"	11.70	2.90		45.86	2.07	37.99	100.52	81.7	R. S. Williamson.
11	Conococheague.		Bet. Chewsville and Security.	....	....		46.82	1.10	37.73	85.65	83.5	H. P. West.
12	"		Security.	....	....		41.68	2.70	35.48	79.86	74.2	H. P. West.
13	"		"	....	....		37.20	5.94	35.55	78.69	66.3	H. P. West.
14	"		"	....	....		46.38	5.83	42.58	94.78	83.6	H. P. West.
15	"		"	6.84	1.04	.26	50.59	1.85	41.76	102.84	90.0	H. P. West.
16	"	S. C. & L. Co.	"	7.38	1.24	.30	48.05	1.41	40.35	99.78	85.6	J. J. Porter.
18	"	"	"	9.13	1.60	.53	48.97	.17	39.02	99.50	87.2	M. R. Schmidt.
19	"	"	"	6.86	.93	.44	50.47	1.20	40.50	99.90	89.8	M. R. Schmidt.
20	"	"	"	5.10	.86	.43	51.72	.84	41.08	99.98	92.0	M. R. Schmidt.
21	"	"	"	8.52	1.57	.56	47.94	1.78	39.95	99.42	85.9	M. R. Schmidt.
22	"	"	"	7.84	1.28	.69	49.60	1.11	39.39	99.95	87.4	M. R. Schmidt.
23	"	"	"	8.42	2.26	.68	48.85	1.84	38.83	99.88	86.2	M. R. Schmidt.

WASHINGTON COUNTY—Continued.

LIMESTONE.

Map No.	Name of limestone.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition	Total.	$CaCO_3$.	Analyst.
24	Conococheague.	S. C. & L. Co.	Security.	6.04	1.96	.62	48.88	1.74	39.30	98.52	87.0	J. J. Porter.
25	"	"	"	6.42	1.51	.49	48.78	1.77	40.70	99.67	86.9	J. J. Porter.
26	"	"	"	4.78	1.29	.61	49.50	2.38	41.18	99.75	88.1	J. J. Porter.
27	"	"	"	3.63	.69	.53	51.44	1.63	42.10	100.13	91.4	J. J. Porter.
28	"	"	"	5.62	1.21	.81	49.78	1.58	40.96	99.96	88.8	J. J. Porter.
29	"	"	"	5.60	1.04	.30	49.11	1.41	40.60	98.51	87.1	J. J. Porter.
30	"	"	"	7.66	1.29	.68	48.72	1.53	39.45	99.38	86.7	M. R. Schmidt.
31	"	"	"	7.28	2.37	.30	49.04	1.75	40.01	100.95	87.2	E. G. Zies.
32	"	"	"	9.52	1.75	.61	48.41	1.18	38.55	100.02	86.2	E. G. Zies.
33	"	"	"	11.24	2.92	.36	46.11	1.45	37.20	99.78	82.0	E. G. Zies.
34	"	"	"	15.31	3.40	1.18	42.85	1.31	35.60	99.65	76.4	E. G. Zies.
35	"	"	"	15.58	3.91	1.07	42.83	1.45	34.38	99.22	76.4	E. G. Zies.
36	"	"	"	14.14	3.57	.32	44.81	1.54	35.21	99.59	78.8	E. G. Zies.
37	"	"	"	12.68	3.33	1.06	43.98	2.24	36.26	99.57	78.3	E. G. Zies.
38	"	"	"	9.62	2.63	.65	46.52	1.66	38.44	99.52	82.8	J. J. Porter.
39	"	"	"	9.24	1.70	1.20	46.71	1.67	39.06	99.58	83.2	J. J. Porter.
40	"		"	5.22	....	.88	52.41	.54	41.15	100.20	93.2	E. G. Zies.
41	"		"	7.48	1.87	.69	47.99	1.26	39.92	98.81	85.5	J. J. Porter.
42	"		"	6.84	3.42	.67	47.08	1.65	39.94	99.80	83.7	J. J. Porter.
43	"	S. C. & L. Co.	"	14.90	3.21	1.53	42.40	1.81	35.72	99.57	75.5	J. J. Porter.
44	"		"	10.30	2.88	1.12	46.45	1.80	37.50	100.55	82.7	J. J. Porter.
45	"		"	5.55	2.16	.81	49.87	1.18	39.99	99.56	89.0	E. G. Zies.
46	"		"	7.08	1.47	.81	48.12	2.08	40.52	100.08	85.6	J. J. Porter.

WASHINGTON COUNTY—Continued.

LIMESTONE.

Map No.	Name of limestone.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
47	Conococheague.		Security.	5.26	1.60	.37	51.96	.69	40.61	100.51	92.4	E. G. Zies.
48	"		"	6.80	2.64		47.38	2.14	39.56	98.52	84.4	J. J. Porter.
49	"		Hagerstown.	10.32	3.64		46.42	2.28	38.30	100.96	82.6	J. J. Porter.
50	"		"	3.34	1.50		51.00	2.17	42.20	100.21	90.6	J. J. Porter.
51	"		"	3.16	1.71		47.25	5.72	41.86	99.64	84.3	R. S. Williamson.
52	"		"	7.52	3.05	.45	48.92	1.76	39.11	100.81	87.0	O. E. Bransky.
53	"		"	16.04	5.27	1.25	41.30	1.50	33.82	99.18	73.7	O. E. Bransky.
54	"		"	14.33	4.89	1.65	42.94	2.01	34.89	100.71	76.4	O. E. Bransky.
55	"		"	4.28	.90	.86	52.29	1.52	41.06	100.91	94.3	O. E. Bransky.
56	"		"	5.51	1.30	.33	51.85	.82	41.10	100.91	92.4	O. E. Bransky.
57	Beekmantown.		"	2.76	1.85	1.07	48.76	2.48	40.75	97.67	86.8	J. J. Porter.
58	"		"	11.16	8.59	.99	37.45	3.03	32.54	93.76	66.8	J. J. Porter.
59	Conococheague.		"	17.30	6.70		41.08	1.98	34.45	101.51	73.3	J. J. Porter.
60	"		"	19.40	5.30		40.80	1.48	33.53	100.46	72.8	R. S. Williamson.
61	"		"	12.70	3.80		45.50	1.59	37.40	100.99	81.0	R. S. Williamson.
62	Beekmantown.		Bet. Williamsport and Hagerstown.	n. d.	n. d.	n. d.	n. d.	2.26	....	....	....	R. S. Williamson.
63	"		"	"	"	"	"	3.04	....	....	....	R. S. Williamson.
64	"		"	"	"	"	"	4.53	....	....	....	R. S. Williamson.
65	"		"	"	"	"	"	16.23	....	....	....	R. S. Williamson.
66	"		"	"	"	"	"	18.30	....	....	....	R. S. Williamson.
67	"		Williamsport.	6.04	1.29	.58	49.68	2.60	40.65	100.84	88.4	Zies and Gill.
68	"		"	4.46	2.13	.97	47.55	2.73	41.44	99.28	84.6	J. J. Porter.

WASHINGTON COUNTY—Continued.

LIMESTONE.

Map No.	Name of limestone.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
69	Beekmantown.		Williamsport.	9.72	1.98	1.04	46.00	2.35	38.06	99.15	81.9	J. J. Porter.
70	Stones River.		"	3.86	1.26	.40	51.75	1.21	42.04	100.53	91.5	J. J. Porter.
71	"		"	4.76	.89	.51	50.81	1.94	41.80	100.21	89.5	J. J. Porter.
72	"		"	7.09	.99	.62	50.78	1.18	40.19	100.85	90.4	J. J. Porter.
73	"	Pot. Val. S. & L. Co.	Pinesburg.	.60	.96		55.00	n. d.	42.90	99.74	97.9	Zies and Gill.
74	"	"	"	.80	1.00		54.50	"	42.88	99.10	97.4	Zies and Gill.
75	"	"	"	.80	1.20		53.00	2.06	43.40	100.46	94.8	Zies and Gill.
76	"	"	"	3.10	1.70		47.25	5.72	43.14	100.91	84.2	Zies and Gill.
77	"	"	"	7.10*	.98		44.44	5.08	40.25	97.85	79.0	J. J. Porter.
78	"	"	"	2.90*	1.10		43.38	8.49	43.14	98.96	77.3	J. J. Porter.
79	"	"	"	7.66*	1.04		40.98	8.55	41.88	99.51	73.0	J. J. Porter.
80	"	"	"	2.28*	1.74		44.26	7.79	43.09	99.16	78.9	J. J. Porter.
81	"	"	"	6.80*	1.82		48.99	1.81	40.20	99.12	87.4	J. J. Porter.
82	"	"	"	5.42*	1.60		45.27	5.65	41.53	99.47	80.6	J. J. Porter.
83	"	"	"	1.12*	1.56		51.70	.69	41.09	96.16	92.5	J. J. Porter.
84	"	"	"	1.46*	1.04		52.91	.80	42.15	98.36	94.3	J. J. Porter.
85	"		"	12.70*	2.46		44.02	1.48	35.96	96.62	78.8	J. J. Porter.
86	"		"	7.40*	2.88		30.59	16.67	25.69	83.23	54.5	J. J. Porter.
87	"		"	11.74*	4.40		42.17	2.31	35.43	86.05	75.1	J. J. Porter.
88	"		"	5.40*	1.30		48.78	2.68	40.89	99.05	86.9	J. J. Porter.
89	"		"	4.90*	1.40		49.61	2.08	40.98	98.87	87.3	J. J. Porter.
90a	"		"	9.90*	1.82		47.54	1.99	39.27	100.52	84.6	Catlett and Porter.
90b	"		"	6.62*	1.50		45.06	5.65	41.36	100.19	80.1	Catlett and Porter.

* "Insol."

WASHINGTON COUNTY—Continued.

LIMESTONE.

Map No.	Name of limestone.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
91	Stones River.		Pinesburg.	2.96*	.84		53.00	1.00	42.44	100.24	94.8	Catlett and Porter.
92	"		"	2.44*	1.20		53.08	1.30	42.79	100.76	94.8	Catlett and Porter.
93	"		"	4.48*	1.42		40.10	11.69	32.56	90.25	71.4	Catlett and Porter.
94	Beekmantown.		Charlton.	2.86	.28	.28	52.24	2.05	42.08	100.14†	93.0	A. J. P., U. S. G. S.
95	"		"	5.72	.12	.56	51.28	1.01	40.91	100.24†	91.3	A. J. P., U. S. G. S.
96	"		"	4.23	1.64	.28	46.79	5.14	41.50	100.04†	83.6	P. H. Bates.
97	"		"	2.72	.59	.16	53.25	.87	42.10	100.06†	94.8	P. H. Bates.
98	"		"	10.46	2.84	.72	42.08	5.11	37.27	99.88†	75.1	P. H. Bates.
99	"		"	2.28	1.06	.24	53.19	1.23	41.61	100.04†	94.7	P. H. Bates.
100	"		"	14.17	3.17	1.00	40.32	4.18	35.37	100.05†	71.7	P. H. Bates.
101	"		"	4.61	.15	.64	34.53	15.99	44.07	100.26†	61.5	P. H. Bates.
102	"		"	14.57	4.27	.90	39.07	4.45	34.39	99.78†	69.7	P. H. Bates.
103	"		"	5.91	1.77	.56	49.56	1.48	39.62	99.91†	88.3	P. H. Bates.
104	"		"	16.20	3.56	.96	39.86	3.44	34.05	100.04†	71.1	A. J. P., U. S. G. S.
105	"		"	10.62	1.70	1.12	35.16	10.37	37.98	100.15†	62.6	A. J. P., U. S. G. S.
106	"		"	4.66	.84	.36	51.42	.76	40.68	100.12†	91.5	A. J. P., U. S. G. S.
107	"		"	3.14	.24	.48	51.94	1.61	41.71	100.03†	91.4	A. J. P., U. S. G. S.
108	"		"	15.98	4.18	1.28	37.50	5.69	33.89	100.17†	66.9	A. J. P., U. S. G. S.
109	"		"	14.28	2.06	1.20	43.56	2.32	35.06	100.07†	77.6	A. J. P., U. S. G. S.
110	"		"	2.30	.51	.16	53.06	1.17	42.20	100.08†	94.5	P. H. Bates.
111	"		"	5.66	1.69	.52	50.49	.71	39.85	99.94†	89.9	P. H. Bates.
113	"		"	3.99	1.25	.82	51.99	.65	40.93	100.07†	93.6	P. H. Bates.
114	"		"	3.10	1.11	.33	51.91	.85	41.44	99.81†	93.4	P. H. Bates.
115	"		"	5.76	1.12	.92	49.86	.97	40.30	100.14†	89.0	A. J. P., U. S. G. S.

* "Insol."

† Includes MnO: Alkalies: SO_3; H_2O.

WASHINGTON COUNTY—Continued.

LIMESTONE.

Map No.	Name of limestone.	Quarry.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignation.	Total.	$CaCO_3$.	Analyst.
116	Cayuga.		Hancock.	51.65	2.57	.68	50.48	.76	40.17	100.41	89.9	E. G. Zies
117	"		"	3.80	4.00		50.14	1.16	40.65	99.75	89.2	T. M. Price.
118	"		Round Top.	19.81	7.85	2.41	35.76	3.18	30.29	97.80	63.8	C. Richardson.
119	"		"	27.1	1.5		36.40	2.52	31.16	98.98	64.7	C. Huse.
120	"		"	26.07	11.40	3.17	28.05	3.44	25.94	98.17	50.0	E. G. Zies.
121	"		"	20.16	6.84	1.36	28.56	2.07	31.74	100.28	50.9	E. G. Zies.
122	Helderberg.		Gt. Cacapon.	21.72	5.88	1.85	36.91	2.10	30.91	99.37	65.0	E. G. Zies.
123	"		"	19.71	6.33	1.48	34.06	6.47	31.84	99.89	60.8	E. G. Zies.
124	Beekmantown.		Grimes.	3.60	1.80		51.00	2.39	42.41	101.20	90.8	R. S. Williamson.
125	Stones River.		Williamsport.	6.60	2.80		49.50	1.81	40.77	101.48	88.3	R. S. Williamson.
126	"		"	10.80	2.40		43.60	4.13	38.68	99.61	77.6	R. S. Williamson.
127	"		"	7.80	1.40		49.60	1.55	40.56	100.91	88.3	R. S. Williamson.
128	"		"	4.10	3.70		50.20	1.19	40.64	99.83	89.4	R. S. Williamson.
129	"		"	4.00	3.80		49.80	1.41	40.57	99.58	88.6	R. S. Williamson.
130			Butner.	3.71	1.89	.32	45.37	4.67	39.46	100.42	80.9	Zies and Gill.
131			"	3.36	2.76	.90	46.42	2.74	39.39	100.57	82.7	Zies and Gill.
133	Conococheague.		Grimes.	3.50	3.20		47.05	2.68	39.45	100.88	83.8	R. S. Williamson.
134			"	9.48	1.71	.75	46.85	2.30	38.54	99.63	83.6	O. E. Bransky.
135			Keedysville.	3.21	4.21		51.44	.34	40.72	99.92	91.0	T. M. Price.
136				21.98	17.84	2.67	20.20	4.61	30.39	97.69	36.0	Zies and Gill.
137			Antietam.	15.23	9.21	1.65	26.53	11.55	35.67	99.84	41.2	Zies and Gill.
138			Sharpsburg.	3.40	1.34		47.60	5.32	43.10	100.76	84.8	R. S. Williamson.
139			"	1.79	3.49		46.66	5.49	42.65	100.08	83.2	T. M. Price.
140			"	15.97	7.59		23.72	15.60	20.22	83.10	42.2	C. Richardson.
141			"	19.20	3.30		23.20	9.78	29.24	99.82	41.3	R. S. Williamson.

WASHINGTON COUNTY.

ARGILLACEOUS MATERIALS.

Map No.	Name of shale.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Alkalies.	Ignition.	Total.*	Analyst.
1	Harpers.	Edgemont.	62.80	20.22	6.02	1.10	2.08	....	4.00	....	
2	"	"	60.88	20.9	6.68	1.00	1.81	....	3.70	....	
3	Martinsburg.	Hagerstown.	59.46	20.24	4.82	1.09	1.77	....	9.52	96.90	J. J. Porter.
4	"	"	59.20	25.66		3.16	2.04	....	....	....	J. J. Porter.
5	"	"	59.74	22.68	3.16	.73	2.48	....	7.73	96.42	
6	"	"	59.94	22.87	2.61	.64	2.29	....	7.56	95.91	J. J. Porter.
7	"	"	59.56	21.97	3.90	.84	2.58	....	7.74	96.68	J. J. Porter.
8	"	"	59.44	22.74	2.34	2.00	1.87	....	8.94	97.33	J. J. Porter.
9	"	"	59.72	23.04	2.88	1.30	2.42	....	7.90	97.26	J. J. Porter.
10	"	"	62.20	19.01	7.47	.20	.94	....	6.24	95.86	J. J. Porter.
11	"	Pinesburg.	64.23	21.23	4.97	.62	1.72	1.25	5.09	100.11	A.J.P.,U.S.G.S.
12	"	"	58.58	18.75	6.27	4.66	2.71	1.92	6.59	100.06	A.J.P.,U.S.G.S.
13	"	"	59.20	25.66		3.16	2.04	....	....	....	J. J. Porter.
14	"	"	50.96	25.63	4.37	5.40	2.48	....	10.14	98.83	J. J. Porter.
15	Romney.	Gt. Cacapon, W. Va.	68.08	14.65	6.17	1.28	.50	....	4.24	94.87	E. G. Zies.
16	Jennings.	" "	65.65	18.70	5.91	.65	1.41	....	5.16	97.48	E. G. Zies.

*Analyses incomplete.

SUMMARY AND STATISTICS FOR WASHINGTON COUNTY.

The limestones of Washington County are most abundantly developed in the Hagerstown Valley where they have been worked especially along the Western Maryland Railroad, the largest operations being at Cavetown, Hagerstown, Halfway, and Pinesburg. Other quarries and numerous kilns are found scattered over the valley.

The exposures of satisfactory limestones are frequent in the western portion of the county, but few of them are capable of commercial development on account of their present inaccessibility. Where the various limestone strata cross the lines of the Western Maryland Railroad and the Chesapeake and Ohio Canal these deposits are accessible and offer many opportunities for the development of cement, lime, and stone industries.

Washington County ranks first in the production of limestone for ballast, road-metal, concrete, etc., due to the large railway mileage and demand for crushed stone in railroad construction and maintenance. In spite of the fact that the county contains a great abundance of limestone in areas traversed by several railroads, it ranks third in the production of lime. One of the reasons why the amount of lime made in Washington County is small in proportion to the available raw material is because the average quantity of lime used for agricultural purposes is less per acre of area than it is in any of the other four principal lime-producing counties in the State, with the exception of Allegany. Moreover, its distance from Baltimore and Washington, the two leading markets for building lime, prohibits the Washington County lime operators from entering into strong competition with the producers who are located nearer these two markets.

The inception of a new industry—that of manufacturing Portland cement—at Security has aroused renewed interest in the resources of the region. With the promised success of this plant, and others which may follow, the value of the annual production of cement will greatly exceed that of any other forms in which the limestones are used. At present the annual production of lime is valued at $20,000, and the crushed

stone at from $65,000 to $100,000, depending upon the demand for material in railroad and highway construction.

The list that follows below gives the names of the large as well as the small lime and limestone producers operating within the limits of Washington County:

LIME AND LIMESTONE OPERATORS IN WASHINGTON COUNTY.

OPERATOR.	OFFICE.	QUARRY.
Angle, S. P.	Hagerstown	Hagerstown.
Besore, Geo. N.	Smithsburg	Smithsburg.
Beverly Granite Co.	Beverly, S. C.	Halfway.
Brown and Bachtell	Smithsburg	Edgemont.
Clarkson Brothers	Hagerstown	Hagerstown.
Creeger, J. Wesley	Thurmont	Thurmont.
Hagerstown City Quarry	Hagerstown	Hagerstown.
Hagerstown Macadam Co.	"	"
Horst, D. E.	Maugansville	"
Hose, Geo. W.	Clear Spring	Dry Run.
Keedy, D. D.	Keedysville	Rohrersville.
Little, Frank P.	Hancock	Hancock.
McKee, James F.	Clear Spring	Clear Spring.
Md. Ala. Marble Co.	New York	Benevola.
The Md. Quarry Co.	Williamsport	Williamsport.
Miner, George F.	Smithsburg	Edgemont.
Moser, Joseph F.	Thurmont	Thurmont.
Nutter, Daniel R.	Maugansville	Maugansville.
Potomac Valley Stone Co.	Hagerstown	Pinesburg.
Rines, L. C.	Eakles Mills	Boonsboro.
Rohrer Bros.	Smithsburg	Smithsburg.
Shinham, Geo. W.	Hagerstown	Cearfoss.
Smith, Vernon T.	Lewistown	Thurmont.
Strock, J. C.	Hagerstown	Cearfoss.
Union Stone Co.	York, Pa.	Halfway.
Wade, J. Hubert	Boonsboro	Sharpsburg.
Washington Marble Co.	New York	Eakles Mills.
Zouck, P. G. & Co.	Cavetown	Cavetown.

ALLEGANY COUNTY.

GEOGRAPHICAL LIMITS.

The area embraced within the limits of Allegany County is high and mountainous. It is crossed along its southern border by the Western Maryland Railroad, while a portion of this county is also traversed by the Baltimore and Ohio. Other lines centering at Cumberland by following valleys and by taking advantage of the gaps in the mountains, tap the coal-fields, and furnish a means of transportation into Pennsylvania.

GEOLOGY.

The rocks exposed in Allegany County range in age from Silurian to Carboniferous. These have been folded into major synclines and anticlines, upon which are minor flexures of a similar sort. Faults are also known to occur, but, as a rule, the normal stratigraphy has been but little disturbed by them. The nature of the folding is well shown in the gap cut by Wills Creek through the mountain of the same name just west of Cumberland. Synclines alternate with anticlines throughout the whole of this area, but the deformation becomes less pronounced passing from east to west.

The geological formations of Allegany County of special interest in the present discussion are as follows:

	Limestones.	Shales.
Carboniferous......	Greenbrier.......	Mauch Chunk.
Devonian..........	Helderberg.....	Hampshire. Jennings. Romney.
Silurian...........	Cayuga.	

The geological characteristics of each of these formations, with the exception of the Carboniferous Greenbrier limestones and Mauch Chunk shales, have been described in detail in the preceding discussion of Washington County, and need not be redescribed for Allegany County where they present the same general features.

The limestone and shale formations of Allegany County cross it in a northeast and southwest direction, and are generally traversed by the railroads at more or less acute angles to the strike of the formations by reason of the fact that the railroad routes have been controlled principally by the topography. But this is immaterial, so far as the shales are concerned, because of their great thickness and wide distribution; it has, however, an important bearing on the commercial development of the limestones, which are much thinner than the shales, and have their workable areas restricted and confined to a few localities. The sections in which the limestones are exposed to best advantage for quarrying occur in the valleys east and west of Wills Mountain. The Helder-

berg and Cayuga limestones are both worked on the east side of this mountain in the vicinity of Cumberland. To the west of Wills Mountain they are well exposed along the lines of the Baltimore and Ohio and Pennsylvania Railroads, between Mt. Savage Junction and Corriganville, while the same beds have been worked further southwest on their strike at Potomac, where they are crossed by the Baltimore and Ohio and Western Maryland railroads. Between Rawlings and Dawson the Helderberg is exposed along both transportation routes for a distance of about 5 miles. This is because these two lines follow the formation across an anticlinal area for considerable distances parallel to the strike. The Helderberg is also well exposed on the Baltimore and Ohio Railroad northeast of Dawson, where the quality of the stone is probably such as to make it valuable for use in the manufacture of cement or for burning into lime.

In cement manufacture the Devonian shales are the most accessible for use in conjunction with Cayuga and Helderberg limestones. On the other hand, the Carboniferous shales are most advantageously situated with reference to the Greenbrier limestone.

Limestones.

The Greenbrier formation belongs to the Mississippian or lower division of the Carboniferous. Stratigraphically, it is above the Pocono sandstone and beneath the Mauch Chunk red shale, and usually occupies valleys or sides of valleys which are flanked by ridges upheld and maintained by the more resistant Pocono.

In Maryland the Greenbrier limestone is probably the least important economically of all the limestone formations. However, if followed southwestward into West Virginia, it grows thicker and purer, and becomes of increasing commercial importance. In Maryland it attains a thickness of about 300 feet and consists mainly of shales, but contains also beds of limestone and sandstone. The beds of limestone are inclined to be siliceous, becoming more sandy near the contact of this formation with the Pocono. Their color is gray and brown, and when weathered the more siliceous layers stand out as minor ridges,

FIG. 1.—GREENBRIER LIMESTONE, WEST OF CORRIGANVILLE.

FIG. 2.—HELDERBERG-CAYUGA LIMESTONES, DEVIL'S BACKBONE, CORRIGANVILLE.

VIEWS OF ALLEGANY COUNTY LIMESTONE EXPOSURES.

while the less sandy parts between occur as furrows. This corrugated weathering is shown in Plate XXV, Fig. 1.

The Greenbrier limestone crosses transportation routes in Allegany County at but three points. The first of these is 1¼ miles east of Barrellsville, on the Cumberland and Pennsylvania Railroad; the second is 3 miles east of Eckhart Mines, on the same road as the above, which is paralleled at this point and further east by the Georges Creek and Cumberland Railroad; the third is about 2 miles east of Westernport.

Shales.

The most important of the argillaceous materials of Allegany County are of Devonian age. These occur widely distributed and closely associated with the Helderberg and Cayuga limestones, as shown on the geological map of the State. In general, the chemical composition of these shales is such as to make it quite an easy matter to locate deposits suitable for Portland cement manufacture.

The fact that the base of the Romney formation is separated stratigraphically from the Helderberg by a thickness of only about 350 feet of Oriskany sandstone, while the latter rests, in turn, on the Cayuga formation, assures the economic assembling of limestone and shale at a Portland cement plant built at some convenient point on or between these calcareous and argillaceous formations.

The Devonian shales of Allegany County differ in no essential respects either as regards chemical composition or physical characteristics from the shales of the same age already described as occurring in Washington County. In both counties, but particularly in Allegany, they attain an enormous thickness and cover much larger areas than any of the other formations that are found intimately associated with them.

DISTRIBUTION OF LIME AND CEMENT MATERIALS OF ALLEGANY COUNTY.

Cayuga and Helderberg Limestones.

CORRIGANVILLE.—Northeast of Corriganville the Pennsylvania Railroad passes through the gap made by Wills Creek in the high ridge that

parallels Wills Mountain on the west. The railroad cuttings expose both the Helderberg and the Cayuga, the former in contact with the Oriskany sandstone on the west.

After the railroad tracks pass round the ridge in question they follow in a northeastern direction on and close to the contact of the Oriskany and Romney shale all the way to the Pennsylvania-Maryland line. On the west side of the ridge, where the tracks curve sharply from west to north, the railroad company owns and operates a large quarry from which the lower cherty strata of the Oriskany are quarried and crushed for ballast. Analyses of samples of this material are as follows:

ANALYSES OF ORISKANY CALCAREOUS CHERT, CORRIGANVILLE.

	No. 6.	No. 7.	No. 8.	No. 9.
Silica (SiO_2)	48.54	53.21	56.07	69.82
Alumina (Al_2O_3)	5.50	4.22	4.02	4.97
Iron oxide (Fe_2O_3)	2.21	1.66	1.26	1.59
Lime (CaO)	22.29	21.98	20.88	13.76
Magnesia (MgO)	1.05	.55	.46	.10
Alkalies ($Na_2O + K_2O$)	1.50	n. d.	n. d.	n. d.
Ignition	18.23	18.09	16.98	10.38
Total	99.32	99.71	99.17	100.62

The location of their occurrences are indicated by corresponding numbers on the general map. From these analyses it will be seen that the Oriskany is increasingly less siliceous the nearer its beds are to the base of the formation where it is in contact with the Helderberg.

In cutting through the ridge referred to above, Wills Creek has left on its north side a sharp and steep escarpment. The strata stand almost on end. One of the beds rising higher than the rest from a thickness of 16 feet at the level of the railroad track, narrows down to a sharp and ragged edge that cuts through the very crest of the cliff, and stands out as a most striking topographic feature. This has been given the name "Devil's Backbone," and is famous as a bit of local scenery. A photograph of the "Devil's Backbone," is reproduced as Plate XXIV, Figure 2.

Samples were taken of the "Devil's Backbone" and certain of the accompanying beds, as shown in the diagram, Figure 26. The bed of

limestone called the "Devil's Backbone" is Helderberg in age. Its position in the formation is indicated in the following measured section, which gives the succession of beds from the topmost down. The contact of the Helderberg in the "Devil's Backbone" ridge with the Oriskany sandstone on the west, is just back of the section house.

Beginning with the bed of the Helderberg in contact with the Oriskany the first 64 feet in the section quoted below are assigned to the New Scotland, or middle member of the Helderberg, the Becraft, or the upper member, being absent at this point. The lower 110 feet are referred to the Coeymans.

HELDERBERG LIMESTONE SECTION AT DEVIL'S BACKBONE.

	Thickness feet.
NEW SCOTLAND.	
(a) Soft and bluish argillaceous shales with some indurated layers. Occasional manganese phosphatic nodules	20
(b) Massive-gray limestone with bands of chert becoming thin-bedded above and containing beds of shales	44
COEYMANS.	
(c) Massive regularly bedded blue-gray limestone. (The sharp ridge of the "Devil's Backbone.") (Analysis No. 5½)	16
(d) Thin bed of shaly limestone	1½
(e) Massive regularly bedded, blue-gray to dove-colored non-fossiliferous limestone. (Analysis No. 5)	22
(f) Heavy-bedded gray nodular limestone filled with *stromatopora* known as the "first stromatopora bed." (Analysis No. 4)	1½
(g) Heavy-bedded blue limestone almost without *stromatopora*. (Analysis No. 3)	25
(h) "Second stromatopora bed" abounding in a few species of corals	9
(i) Thin-bedded nodular limestone with occasional *stromatopora*	10
(j) Heavy-bedded grayish limestone with layers of chert more prominent above than below. Fossils are rare. (Analysis No. 2)	32½

All of the Coeymans, the lower member of the Helderberg section at the "Devil's Backbone," was sampled, as stated in the foregoing, with the exception of the 19 feet above the 32 feet of heavy-bedded, grayish limestone at the base of the formation. One reason why this 19 feet was not sampled was because of the close lithological similarity of most of it to the first *Stromatopora* bed. The analysis of the latter may,

therefore, be taken to indicate the approximate composition of the former.

The upper 40 feet of Cayuga limestone, underlying the Coeymans of the Helderberg, the one grading almost imperceptibly into the other, consists of blue, cherty limestone above and massive limestone at the bottom, with soft and shaly beds between.

A sample of this was taken, and its composition is represented by analysis No. 1.

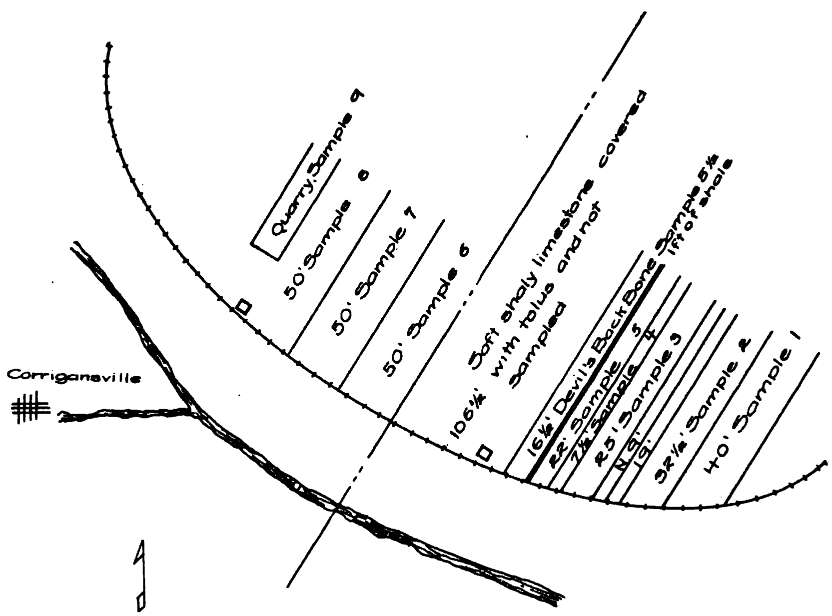


FIG. 26.—Diagram showing source of samples analyzed from Corrigansville, Maryland.

The following gives the average composition of the set of samples described above:

AVERAGE COMPOSITION OF HELDERBERG LIMESTONE AT "DEVIL'S BACKBONE," CORRIGANVILLE.

Silica (SiO_2)	13.43
Alumina (Al_2O_3)	2.10
Iron oxide (Fe_2O_3)	.83
Lime (CaO)	45.10
Magnesia (MgO)	1.41
Ignition	37.01
Total	99.88

Stone of the above composition would require the admixture of very little shale of correct composition to manufacture into Portland cement. Such shales could be had near at hand from the Romney formation, a 120-foot sample of which was taken west of Corriganville, on the road to Barrellsville, at No. 1 of the map.* Material of the same composition may be had on the line of the Baltimore and Ohio Railroad.

ALLEGANY GROVE.—Another place where limestone occurs of suitable composition for Portland cement is at Cash Valley, west of Wills Mountain, between Allegany Grove and Narrows Park. This point is about midway between the two stations in the small gap in the ridge nearly ½ mile west of where the Eckhart Branch of the Cumberland and Pennsylvania Railroad crosses to the east side of the turnpike. The Helderberg limestone has been quarried here and burned into lime.

The analysis quoted below was made on a 66-foot sample taken at the point indicated by No. 16 on the map. The limestone exposed here was found to be cherty near the top, massive near the middle, and shaly below:

ANALYSIS (NO. 16) OF HELDERBERG LIMESTONE, CASH VALLEY, NEAR ALLEGANY GROVE.

Silica (SiO_2)	12.01
Alumina (Al_2O_3)	1.54
Iron oxide (Fe_2O_3)	.75
Lime (CaO)	47.06
Magnesia (MgO)	1.05
Ignition	37.69
Total	100.10

West of the quarry, where the sample analyzed above was obtained, Romney shales occur in great abundance, and in conjunction with limestone like that above could be used to manufacture Portland cement.

CUMBERLAND.—The same limestone formations that were sampled at the "Devil's Backbone," near Corriganville, occur along transportation routes on the east of Wills Mountain at Cumberland. Both the Helderberg and the Cayuga have been quarried here and made into lime, and

* See shale analysis No. 1.

the former also into natural cement by the Cumberland Hydraulic Cement and Manufacturing Company. The Cumberland Hydraulic Cement and Manufacturing Company is capitalized at $2,000,000, and has a plant with a capacity of 1000 barrels in 10 hours. The cement mill is located at Cumberland and is equipped with ball and tube mills, so that the natural hydraulic cement clinker in grinding is put through a quadruple process with the same sort of machinery as that employed in grinding Portland cement, producing an equal fineness in the product. Cement was first made here in 1836. The quarries are in the south bank of Wills Creek, where the Helderberg rocks are so folded and exposed that the beds can be conveniently worked. The following is a fairly typical but poor analysis of the material used:

ANALYSIS (NO. 13) OF CAYUGA LIMESTONE, "NATURAL CEMENT ROCK," CUMBERLAND.

Silica (SiO_2)	24.74
Alumina (Al_2O_3)	16.74
Iron oxide (FeO)	6.30
Lime (CaO)	23.41
Magnesia (MgO)	4.10
Alkalies ($Na_2O + K_2O$)	6.18
Sulphuric acid (H_2SO_4)	2.22
Ignition	18.99
Total	102.68

POTOMAC.—The works of the Cumberland and Potomac Cement Company are at Potomac, or "Pinto," on the Baltimore and Ohio Railroad 9 miles west of Cumberland. The plant is situated on the north side of the railroad, and was first operated in 1891. The raw materials are obtained from the cement beds of the Cayuga and burned directly into natural hydraulic cement. The works have a capacity of 600 barrels a day.

The "4th cement bed" is on the north side of the railroad, and about midway between the plant and the railroad bridge over the Potomac-Cresaptown road. When the plant is in operation argillaceous limestone is mined from this, and the three other beds that occur in the Cayuga. A sample of the "4th cement bed" was taken. This in-

cluded the 15 feet of the material between the foot and hanging walls, on which the mud cracks that were formed at the time of their original deposition may be clearly seen.

ANALYSIS (No. 18) OF CAYUGA LIMESTONE, "NATURAL CEMENT ROCK, 4TH CEMENT BED," POTOMAC.

	No. 18.
Silica (SiO_2)	17.60
Alumina (Al_2O_3)	5.66
Iron oxide (Fe_2O_3)	3.01
Lime (CaO)	35.44
Magnesia (MgO)	4.77
Ignition	32.74
Total	99.22

The Cayuga limestone near the works of the Cumberland and Potomac Cement Company might be used also in the manufacture of Portland cement. It occurs of suitable quality and in good form for quarrying at the point where the Baltimore and Ohio Railroad crosses the Potomac-Cresaptown road, about ¼ of a mile or more west of the plant. Here three samples of limestone were taken, which represent an aggregate thickness of 141 feet of stone. The strike of the beds is N. 45° E. and their dip 45° W.

Sample (No. 27) was taken east and across the road from the house owned by Mr. Rawlings, north of the grocery store near the railroad. The 47 feet of material included in this sample consisted of dove-to-gray-colored limestone, blue on fresh fracture, with occasional thin beds more or less shaly. The analysis shows that it contains very little magnesia, and being high in silica would require a small amount of shale when it comes to mixing the two to manufacture Portland cement:

ANALYSES OF CAYUGA LIMESTONE, POTOMAC.

	No. 27.	No. 26.	No. 25.
Silica (SiO_2)	11.26	9.11	7.30
Alumina (Al_2O_3)	2.39	2.18	1.85
Iron oxide (Fe_2O_3)	.97	.99	.87
Lime (CaO)	47.03	47.76	49.65
Magnesia (MgO)	.88	.96	.88
Ignition	37.56	38.82	39.59
Total	100.09	99.82	100.14

The next sample, No. 26, was obtained representing 44 feet of limestone, massive above and thin-bedded and shaly below, situated stratigraphically below sample No. 27. This analyzed as indicated.

Sample No. 25 represents 50 feet of heavy, bedded limestone lying below the preceding, the top bed of which crosses the railroad at the east abutment of the bridge previously mentioned. The bottom ledge lies to the east of a small spring on the north side of the railroad track.

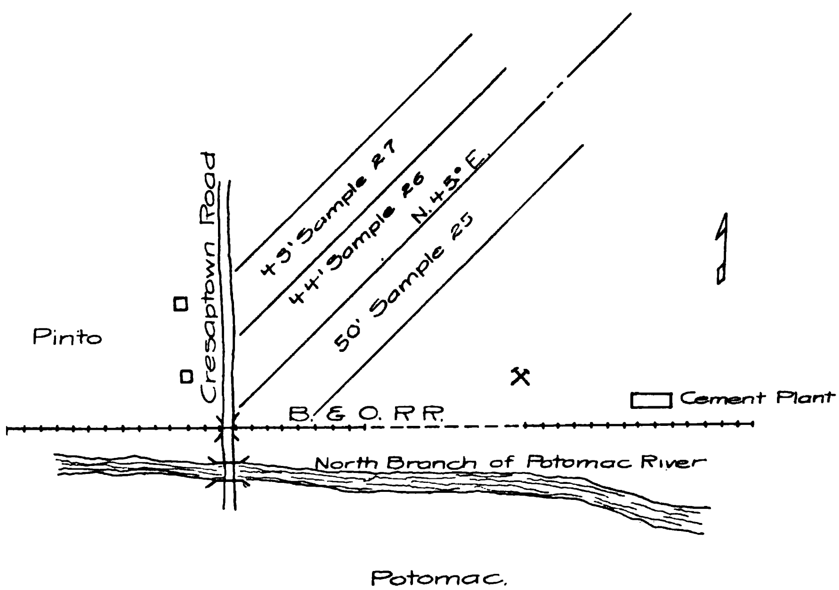


FIG. 27.—Diagram showing source of samples analyzed from Potomac, Maryland.

Utilizing this limestone, which is strikingly similar in composition to that on the property of the Security Cement and Lime Company at Security, about 2 miles west of Hagerstown, the plant of the Cumberland and Potomac Cement Company might, by the installation of the necessary machinery, again be put into operation manufacturing Portland cement. Both shale and argillaceous limestone are also near at hand.

FIG. 1.—QUARRY OF CUMBERLAND HYDRAULIC CEMENT COMPANY, CUMBERLAND.

FIG. 2.—QUARRY OF CUMBERLAND AND POTOMAC CEMENT COMPANY, POTOMAC.

VIEWS OF ALLEGANY COUNTY CEMENT ROCK QUARRIES.

The plant would be at a disadvantage in being situated further from the principal markets of the State than some of its competitors, but it would control the western markets of Maryland and the markets of the adjoining sections of West Virginia and Pennsylvania, and would have an advantage over other works located further east, in the matter of fuel, which the Potomac plant might get from West Virginia at a much cheaper rate.

RAWLINS.—The following analyses were made on samples of limestone taken west of Rawlins on the Baltimore and Ohio. The first of the samples (No. 28) was selected so as to include a stratigraphic thickness of 20 feet, the beds of limestone represented dipping east, with the hanging wall above, a distance of 3750 feet, measured along the tracks of the Baltimore and Ohio Railroad west of Rawlins. Several other samples were taken stratigraphically below this first one. In the second sample (No. 30) 25 feet is represented, and in the third (No. 31) and fourth (No. 29) 34 and 60 feet, respectively; or, in other words, a total consecutive thickness of 134 feet. The foot wall of the beds included in sample (No. 29) is marked by a *Stromatopora* bed which, according to the recent work of Dr. T. Poole Maynard, indicates the line here between the Coeymans and the Cayuga.

The beds of limestone referred to above as having been sampled at the points mentioned,* rise abruptly above the level of the railroad. But here, on the convex side of the first large bend of the Potomac west of Rawlins, where the samples were taken, the topography is such that with two railroads at the base of the cliff occupying the only level area between a steep acclivity on the one side and the river on the other, the opening of a quarry would at first be fraught with some difficulties. However, these could be overcome. The analyses of the samples taken are as follows:

* Analyses following below.

ANALYSES OF LIMESTONE SAMPLES, 1 MILE W. RAWLINS.

	No. 28.	No. 29.	No. 30.	No. 31.
	Thickness of stone represented.			
	20 feet.	60 feet.	24 feet.	84 feet.
Silica (SiO_2)	30.61	13.47	12.95	11.72
Alumina (Al_2O_3)	.62	2.69	.47	1.19
Iron oxide (Fe_2O_3)	.70	.95	.68	.75
Lime (CaO)	38.08	43.11	47.71	46.54
Magnesia (MgO)	.81	3.37	.90	2.34
Ignition	29.94	37.21	37.53	38.07
Total	100.76	100.80	100.24	100.61

DAWSON.—The Helderberg limestone is well exposed at a number of other points along the West Virginia Central and Pittsburg Railroad, also on the Baltimore and Ohio Railroad. From a point about 1 mile west of Rawlins the two parallel tracks are within a stone's throw of each other, diverging about a mile beyond Black Oaks to meet and cross one another, and to continue parallel again beyond Dawson. Throughout the distance between the points just mentioned, the two roads follow in their alignment for stretches of considerable length the general strike of the Helderberg formation. About a mile southwest of Black Oaks the Baltimore and Ohio and the West Virginia Central Railroads diverge, as stated above, the former following closely on a surface contour, and so turning from a more southernly course sharply to the west, while the latter has a straight stretch of track from the point of divergence to its bridge across the river. Samples were taken of three successive thicknesses of the thin-bedded and much-folded, more or less, argillaceous ledges of limestone exposed in the side cut in the hill on the north side of the Baltimore and Ohio Railroad, about 500 feet west of the point of curve mentioned in the preceding sentence. The analyses of these samples is given below. The first (No. 32) was taken between an upper stratum, or hanging wall, dipping east and striking across the track 500+ feet west of the point of curve just referred to, and further marked by the emergence from the rock at this point of a small but persistent spring, and the footwall stratigraphically 95 feet below. While it in turn is followed below by samples (Nos. 33-34), respectively, representing 65 and 60 feet. Analysis (No. 35) was made on a bulk sample repre-

senting the limestone formerly worked in the small, abandoned quarry on the west side of the Baltimore and Ohio, and about ¾ of a mile along the track northeast of Dawson:

ANALYSES OF CAYUGA LIMESTONE, BETWEEN DAWSON AND BLACK OAK, BALTIMORE AND OHIO RAILROAD.

	No. 82.	No. 83.	No. 84.	No. 85.
	Thickness.			
	95 feet.	65 feet.	60 feet.	50 feet.
Silica (SiO_2)	3.69	3.82	10.67	9.17
Alumina (Al_2O_3)	1.27	.75	1.28	.90
Iron oxide (Fe_2O_3)	.62	.58	1.16	.72
Lime (CaO)	51.51	51.06	44.55	49.36
Magnesia (MgO)	1.04	1.56	3.28	1.60
Ignition	41.65	41.36	37.86	39.08
Total	99.78	99.13	98.80	100.83

From the above analyses it may be seen that the Helderberg limestone of the anticlinal area under discussion, particularly that portion of it between Black Oak and Dawson, is worthy of careful consideration and investigation on the part of those having in mind the erection of Portland cement plants in the western part of the State. Shale, water, fuel, and transportation facilities are all four here close at hand. It is reported that land has already been bought along the line of the West Virginia Central Railroad, between Dawson and Black Oaks, with the view of erecting a Portland cement plant to use the limestone exposed further southwestward along the strike in West Virginia.

Greenbrier Limestone.

At none of the few points where the Greenbrier limestones occur in Allegany County on railroads is it fit for use for much else than as a road-metal, ballast, and the like. It is usually too siliceous to make into lime and too limited in quantity, even when otherwise suitable for use in the manufacture of cement. Samples were taken at two points, one about 1½ miles east of Barrellville, on the north side of the Barrellville-Corriganville road, and the other on Stony Run.

BARRELLVILLE.—The samples near Barrellville were taken from a quarry operated principally for the purpose of furnishing road-metal for

use on the section of the turnpike from Corriganville to Barrellville. This quarry is located at (No. 10) and is well shown in Plate XXIV, Figure 1. It has a working face of 29½ feet high, including a band of shale 11½ feet thick that separates the limestone into two ledges of about equal thickness. The beds strike N. 25° E. and dip 20° W., and are worked also on the south side of the railroad which is on the opposite side of Jennings Creek. The sample was taken at the quarry first mentioned. The limestone in this quarry, like that in the railroad quarry, is weathered into furrows and ridges that are parallel to the bedding. The stone in both quarries ranges in color from reddish-brown to greenish-gray. It is extremely siliceous, as is evidenced by the analysis that follows below:

ANALYSIS (No. 10) OF GREENBRIER LIMESTONE, NEAR BARRELLVILLE.

Silica (SiO_2)	19.99
Alumina (Al_2O_3)	2.45
Iron oxide (Fe_2O_3)	1.07
Lime (CaO)	42.29
Magnesia (MgO)	.57
Ignition	33.77
Total	100.14

The second set of samples of Greenbrier limestone selected for analysis was obtained as stated on Stony Run. The point where these samples were taken is at Nos. 39-40 of the map a short way up the stream north of where the run crosses the road leading from Westernport to Dawson. The Greenbrier here is not of a sufficient workable thickness to have any commercial importance. Analysis (No. 40) gives the composition of a 7½-foot ledge of blue-gray limestone below the 8 feet represented in the sample on which analysis (No. 39) was made:

ANALYSES OF GREENBRIER LIMESTONE, WESTERNPORT.

	No. 39.	No. 40.
Silica (SiO_2)	13.86	2.94
Alumina (Al_2O_3)	4.58	1.09
Iron oxide (Fe_2O_3)	1.61	.68
Lime (CaO)	43.21	53.44
Magnesia (MgO)	1.50	.10
Ignition	34.87	42.15
Total	99.63	100.40

ALLEGANY COUNTY.
LIMESTONE.

No.	Name of limestone.	Nearest town.	Silica (SiO$_2$).	Alumina (Al$_2$O$_3$).	Iron (Fe$_2$O$_3$).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	CaCO$_3$.	Analyst.
1	Cayuga.	Corriganville.	26.57	3.96	1.78	34.95	1.96	29.66	98.83	62.3	M. R. Schmidt.
2	"	"	16.45	2.94	1.24	42.23	2.26	35.45	100.57	75.3	M. R. Schmidt.
3	Helderberg.	"	3.62	.72	.38	51.81	1.58	42.15	100.26	92.3	M. R. Schmidt.
4	"	"	10.29	1.65	.44	48.73	.72	38.65	100.48	86.7	M. R. Schmidt.
5	"	"	15.63	2.66	.81	42.63	2.32	36.12	100.17	76.0	M. R. Schmidt.
5½	"	"	8.00	.66	.38	50.24	.65	40.01	99.94	89.8	M. R. Schmidt.
6	Oriskany.	"	48.54	5.50	2.21	22.29	1.06	18.28	99.32*	39.7	M. R. Schmidt.
7	"	"	53.21	4.22	1.66	21.98	.55	18.09	99.71	39.2	M. R. Schmidt.
8	"	"	56.07	4.02	1.26	20.88	.46	16.96	99.17	37.2	M. R. Schmidt.
9	"	"	69.82	4.97	1.59	13.76	.10	10.38	100.62	24.6	M. R. Schmidt.
10	Greenbrier.	Barrellville.	19.99	2.45	1.07	42.29	.57	33.77	100.14	75.4	M. R. Schmidt.
11	"	"	5.24	1.98		47.86	3.56	41.12	99.26	84.4	T. M. Price.
12	Cayuga.	Cumberland.	28.72	12.28	5.22	25.54	1.10	21.18	95.52†	45.6	C. Richardson.
13	"	"	24.74	16.74	6.30*	23.41	4.10	18.99	102.68†	41.7	Q. A. Gillmore.
14	Helderberg.	"	12.27	12.88		41.14	0.41	32.54	99.24	73.4	T. M. Price.
14½	"	"	3.51	3.30		52.13	3.05	38.29	100.28	93.0	T. M. Price.
15	Oriskany.	"	57.49	4.40		15.05	5.16	17.46	99.56	26.8	
16	Helderberg.	Allegany Grove.	12.01	1.54	.75	47.06	1.05	37.69	100.10	83.8	M. R. Schmidt.
17	Cayuga.	Potomac.	26.43	8.18		30.32	6.12	28.74	99.79	53.9	T. M. Price.
18	"	"	17.60	5.66	3.01	35.44	4.77	32.74	99.22	63.3	M. R. Schmidt.
19	"	"	17.91	6.14		40.95	1.36	33.00	99.36	73.1	T. M. Price.
20	"	"	20.90	33.14		20.69	4.12	20.77	99.62	36.8	T. M. Price.
21	"	"	14.50	4.40		44.46	0.57	35.40	99.33	79.2	T. M. Price.
22	"	"	34.01	5.60		33.06	0.86	26.92	100.45	59.1	T. M. Price.
23	"	"	16.33	14.48		35.08	2.95	30.72	99.56	62.6	T. M. Price.

*FeO. †Incomplete.

ALLEGANY COUNTY—Continued.

LIMESTONE.

No.	Name of limestone.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
24	Helderberg.	Potomac.	.79	9.08		48.73	1.24	39.56	99.35	86.7	T. M. Price.
25	Cayuga.	"	7.30	1.85	.87	49.65	.88	39.59	100.14	88.8	M. R. Schmidt.
26	"	"	9.11	2.18	.99	47.76	.96	38.82	99.82	85.3	M. R. Schmidt.
27	"	"	11.26	2.39	.97	47.08	.88	37.56	100.09	83.7	M. R. Schmidt.
28	Helderberg.	Rawlins.	30.61	.62	.70	38.08	.81	29.94	100.76	67.9	Zies and Gill.
29	"	"	13.47	2.69	.95	43.11	3.37	37.21	100.80	76.9	Zies and Gill.
30	"	"	12.95	.47	.63	47.71	.90	37.58	100.24	85.1	Zies and Gill.
31	"	"	11.72	1.19	.75	46.54	2.34	38.07	100.61	83.0	Zies and Gill.
32	Cayuga.	Dawson.	3.69	1.27	.62	51.51	1.04	41.65	99.78	91.9	Zies and Gill.
33	"	"	3.82	.75	.58	51.06	1.56	41.36	99.13	91.1	Zies and Gill.
34	"	"	10.67	1.28	1.16	44.55	3.28	37.86	98.80	79.5	Zies and Gill.
35	"	"	9.17	.90	.72	49.36	1.60	39.08	100.83	88.1	Zies and Gill.
37	Helderberg.	Keyser, W. Va.	1.85	1.45		52.57	.63	42.00	98.50	93.5	W. Va. Geol. Survey Report, Vol. III, p. 341.
38	Oriskany. ‡	" "	71.12	4.12	1.56	11.68	.35	9.59	98.42	20.8	M. R. Schmidt.
39	"	" "	71.43	4.09	2.59	10.88	.78	9.14	98.91	19.4	M. R. Schmidt.
39½	Greenbrier.	Westernport.	13.86	4.58	1.61	43.21	1.50	34.87	99.63	76.8	M. R. Schmidt.
40	"	"	2.94	1.09	.68	53.44	.10	42.15	100.40	94.9	M. R. Schmidt.
41	"	"	5.11	3.56		49.88	1.52	39.85	99.92	88.8	T. M. Price.
42	"	"	3.65	8.44		48.01	.63	38.54	99.26	85.6	T. M. Price.
43	"	"	11.52	3.37		41.71	5.25	38.51	100.36	74.2	T. M. Price.

ARGILLACEOUS MATERIALS.

No.	Name of limestone.	Nearest town.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
1	Romney.	Corriganville.	62.05	18.33	7.53	.99	.71	6.21	(§)	(§)	M. R. Schmidt.

* Includes alkalies. † Includes alkalies and SO_3. ‡ Calcareous sandstone. § Incomplete.

Summary and Statistics for Allegany County.

Allegany is more of a mining than an agricultural county. Hence it is not surprising that it ranks fourth in the production of lime, which, as it will be recalled, is burned and used in Maryland mainly for agricultural purposes. In 1908 the lime product of this county was valued at $8540 which was a little less than two-thirds the return brought for limestone quarried and sold for other purposes. The limestone sold for ballast, road-metal, concrete, etc., was valued at $11,664. No cement was reported for this year. The total value for all limestone products was $20,204. The names of the principal operators are listed below:

LIME AND LIMESTONE OPERATORS IN ALLEGANY COUNTY.

OPERATOR.	OFFICE.	QUARRY.
Cumberland Hydraulic Cement and Manufacturing Company	Cumberland	Cumberland.
Tresher, Charles F.	"	Winchester Bridge.
Gunning, J. B.	Cresaptown	Cresaptown.
Miller, C. A. L.	Cumberland	Cumberland.
Oss, Robert	Cresaptown	Cresaptown.

GARRETT COUNTY.

GEOGRAPHICAL LIMITS.

Garrett County includes within its limits that part of Maryland between Allegany County on the east and the State of West Virginia on the west. It lies almost wholly within the limits of the high and broad region of the Allegany Plateau.

GEOLOGY.

The rocks reaching the surface in Garrett County are all sedimentary in origin, and consist of shales and sandstones, the former predominating, which range in age from Devonian to Permian. Besides these is one limestone formation, the Greenbrier, and thin-bedded limestones in some of the Carboniferous formations. The latter are relatively unimportant, and are more valuable as guide members to the coal seams than they are for commercial uses.

The geological formations found in Garrett County are as follows:

TABLE OF GARRETT COUNTY FORMATIONS.

Cenozoic.		
Quaternary.		
Paleozoic.		
Permian (?)		Dunkard.
Carboniferous	Pennsylvanian or Coal Measures	Monongahela. Conemaugh. Allegheny. Pottsville.
	Mississippian	Mauch Chunk. Greenbrier Pocono.
Devonian		Hampshire. Jennings.

These formations are folded into a series of gentle rolls which extend northeast and southwest. Within the limits of the county occur two gently arching anticlines, bringing lower Carboniferous and Devonian formations to the surface, and three gently depressed basins or synclines holding the Carboniferous formations.

Calcareous Materials.

Limestones occur at several horizons in the Carboniferous, but all are relatively insignificant and of no commercial importance except those of the Greenbrier. This formation may be divided into three members. The lowest is very siliceous, grading into the underlying Pocono sandstone, and is of little or no account. The middle members, composed of thin-bedded, sandy limestones and shales, is likewise of little value. This is, moreover, usually hidden or partially covered with wash and vegetation. The upper member, furnishing as it does the main source of lime of this region, is, however, of considerable value, even though it is a comparatively poor deposit. It is about 65 feet in thickness. The following measured section at Friendsville, which is west of the western anticline previously mentioned, gives the lithologic character of this member. Neither the top nor the bottom portions of this upper member are represented in the first of the sections. The second section, however, is fairly representative.

SECTION TWO MILES SOUTHEAST OF FRIENDSVILLE, GARRETT COUNTY.

	Feet.	Inches.
1. Massive limestone	2	
2. Shaly limestone	3	
3. Massive limestone	5	
4. Shale		8
5. Limestone		9
6. Shale		7
7. Massive blue limestone	12	
Total	24	

SECTION ON BALTIMORE AND OHIO R. R., EAST OF CRABTREE, GARRETT COUNTY.*

	Feet.
1. Gray sandstone (Mauch Chunk)	
2. Red shale	5
3. Red shale and limestone	16
4. Red limestone with corals	5
5. Concealed	10
6. Gray shaly and sandy limestone with occasional fossils.	15
7. Massive reddish limestone	15
Total	66

* Martin, G. C. Geology of Garrett Co., p. 97.

The Greenbrier formation occurs at the surface in three entirely separate areas in Garrett County. One of these areas is so complicated in its boundaries that in describing the surface distribution it may be considered as made up of four connected areas, making a total of six Greenbrier areas in the county. The most easterly of these areas is situated parallel to and about ½ mile west of the crest of Savage and Backbone mountains. It enters the county from Pennsylvania ½ mile west of the northeast corner of the county, and extends in a southwesterly direction to the West Virginia line, 1 mile north of Potomac Stone. This belt is about 45 miles long, and from ¼ to ½ mile wide. It occupies a valley between the Pottsville (Savage Mountain) and the Pocono (Little Savage Mountain) ridges. Along the northern end of Backbone Mountain the line of outcrop is, for a large part of the way, up on the mountain-side, but farther south it occupies a series of minor valleys like those along Savage Mountain.

The second area extends along the eastern side of Meadow Mountain in the valleys of Red Run and Meadow Mountain Run, as far as the confluence of the latter with Deep Creek near Thayerville. Thence it extends in the same southwesterly direction, in a similar series of valleys between Hoop Pole Ridge and the ridge of Pottsville rocks to the west of it, to the West Virginia line at a point about 7 miles southwest of Oakland. This belt is about 37 miles long, and from $\frac{1}{8}$ to $\frac{1}{2}$ of a mile wide.

The third area extends from a point near Thayerville, on the one last described, down the valley of Deep Creek to the mouth of Marsh Run, thence up the valley of Marsh Run to McHenry, thence in a westerly direction for about 1 mile, where it bifurcates. One prong extends down the valley of Hoyes Run for about 1 mile, where it dips under the overlying formation. The other extends in a northwesterly direction through a valley to Sang Run. From here it extends up and down the valley of the Youghiogheny River to points $1\frac{1}{2}$ miles north and $2\frac{1}{2}$ miles south of Sang Run, where it dips under the overlying formation.

The fourth area extends from a point on the one last described at McHenry, in a north-northeasterly direction in the valley parallel to and about $\frac{1}{2}$ mile west of Negro Mountain as far as and across the Pennsylvania line. This belt is about 15 miles long and $\frac{1}{8}$ of a mile wide.

The fifth area extends from a point on the third one, about 1 mile east of Sang Run, in a northerly and northeasterly direction until it crosses the Pennsylvania line at Oakton. It occupies a sinuous line of valleys parallel to and about $\frac{1}{2}$ mile east of the crest of Winding Ridge. This belt is about 13 miles long and $\frac{1}{8}$ of a mile wide.

The sixth area enters the county from West Virginia near Cranesville, and extends south along the valley occupied by Pine Swamp and Muddy Creek as far as Browning Mill, and thence up the valley lying west of Snaggy Mountain for about 4 miles. Here it extends across the line into West Virginia.

Argillaceous Materials.

The argillaceous materials of Garrett are widely distributed, forming, as they do, most of the surface area of the county. The shales of

Devonian age have already been described in a previous section. Shales of Carboniferous age would also be available in inexhaustible quantity for Portland cement manufacture. There is no prospect, however, of either these or the Devonian shales being used for this purpose, since, so far as known, there are no occurrences of limestone in Garrett County where the limestone is of suitable quality and quantity to enter with the shales into a Portland cement mixture.

GARRETT COUNTY—LIMESTONES.

No.	Nearest Town.	Quarry.	Silica (SiO_2).	Alumina (Al_2O_3). Iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Ignition.	Total.	$CaCO_3$.	Analyst.
1	Piney Grove.	Findley.	4.47	2.70	48.57	3.04	41.50	100.28	86.73	T. M. Price.
2	Floyds.		8.57	2.38	53.24	.41	35.94	100.54	88.73	T. M. Price.
3	Thayerville.		20.95	41.10	20.92	.43	16.91	100.31	37.35	T. M. Price.
4		Orffutt.	17.00	2.74	35.91	7.50	44.16	99.61	64.12	T. M. Price.
5	Friendsville.	Gerringer and Neflehart.	13.65	5.44	44.33	.57	35.46	99.46	79.16	T. M. Price.
6	Crellin.	Orffutt.	13.46	12.48	40.85	.55	32.67	100.01	72.92	T. M. Price.

SUMMARY AND STATISTICS FOR GARRETT COUNTY.

The Greenbrier limestone is used extensively for making lime for local consumption. The lime that is obtained from calcining the Greenbrier is used chiefly for agricultural purposes. Also this formation is worked to a limited extent as a road-making material. The statistics of the amount and value of the production used for various purposes are, however, not available. This is due mainly to the fact that the operations are on a small scale, are more or less intermittent, and so most of the operators fail to make their reports to the State Geological Survey. In the absence, however, of detailed data it will suffice to say that the total output and its value is known to be small.

THE COASTAL PLAIN MARLS.

The Coastal Plain marls are more likely to be used for burning to agricultural lime than as an ingredient in Portland cement, and probably will never be used to any great extent for either. Nowhere in Maryland are they found both in sufficient thickness and of suitable chem-

ical composition to be used in the manufacture of Portland cement. It is obvious that both these requirements—namely quality and quantity of materials—must be met if the marls of this section are to form the basis of the industry just mentioned. Nor would they be employed for making lime except for the absence where they occur of any other calcareous material of better quality. Usually it is cheaper to buy lime in some other section and ship it to its destination in the Coastal Plain, paying the additional cost of transportation, rather than attempt to manufacture lime from the local raw material.

The land in the Coastal Plain, however, is sadly in need of lime, but its cost under present conditions is high, and because of this the shell marls are occasionally calcined to obtain lime for use for local agricultural purposes. With the introduction of hydrating plants at most of the Maryland kilns, especially those of Baltimore County, it will be possible to manufacture a product that can be shipped safely by water and sold in the Coastal Plain region of the State at a reasonable price. At present the excessive cost is due largely to the high tariff charged on caustic lime because of the danger of fire always involved in shipping it by boat. Water transportation is the chief, if not the only convenient means of reaching a large portion of the Coastal Plain, and so if lime is to be shipped at a moderate rate and sold at a reasonable cost, it must be hydrated to eliminate from the lime its most dangerous and objectionable feature; the manufacturer of hydrated lime may thus develop with the product—i. e., hydrate lime —a large, profitable, and almost entirely new market.

The writers have examined a large number of occurrences of Eocene and Miocene marls, and of the total number only a very few had sufficient economic importance to require sampling for analysis. One of the best of the deposits seen is found near Marlboro, the county seat of Prince George's, as a ledge in the Aquia formation. As Marlboro is a station, both on the Chesapeake Beach Railroad and on the Popes Creek Branch of the Philadelphia, Wilmington and Baltimore Railroad, the station on the former being called Upper Marlboro, the deposit is well situated for bringing in fuel and sending out the finished product.

Unfortunately, the quality of the best exposures seen, represented by the accompanying analysis, could be used only for burning lime for local consumption. Analysis follows below:

ANALYSIS OF INDURATED SHELL-MARL FROM THE AQUIA FORMATION, MARLBORO, PRINCE GEORGE'S COUNTY.*

Silica (SiO_2)	19.70
Alumina (Al_2O_3)	1.53
Iron oxide (Fe_2O_3)	4.63
Lime (CaO)	39.96
Magnesia (MgO)	1.11
Ignition	33.08
Total	100.01

* East of road north from Marlboro. 500 feet S. of fork to Marlboro station. Thickness of bed about 8 feet.

Another exposure of shell marl, where the marl is considerably thicker than near Marlboro, is that at Mackall's Wharf, St. Leonard's Creek, at its juncture with the Patuxent. The total thickness of the marl is not exposed at this locality, but its estimated thickness is about 12 feet, of which 9 feet is exposed. The sample taken here analyzed as follows:

SAMPLE OF MIOCENE MARL, MACKALL'S WHARF, CALVERT COUNTY.

Silica (SiO_2)	52.54
Alumina (Al_2O_3)	1.32
Iron oxide (Fe_2O_3)	.54
Lime (CaO)	25.21
Magnesia (MgO)	.85
Ignition	19.99
Total	100.45

Shell marl of a similar sort is found exposed also at Jones Wharf, which, in a straight line a few degrees south of west, is about 4 miles west of Mackall's Wharf, but on the opposite side of the river from the latter. The marl bed here is exposed for 2½ to 3½ feet above water, and, as at Mackall's, consists of shells more or less tightly cemented together by an arenaceous-calcareous cement. Because of its high content of silica it is not suitable for use for lime burning, though in the pulverized

state it would doubtless be used as a fertilizing material with satisfactory results. At both these places mentioned the shell marl occurs as a member of the Choptank formation, which, stratigraphically, is the middle one of the three formations in Maryland, comprising the Chesapeake group of the Miocene.

Above the Choptank formation shell marl occurs also in the St. Mary's formation. Usually it is not of a workable thickness, and nowhere has it any economic importance. The following is the analysis of a sample taken about midway between Chancellor and Windmill, points on the east side of St. Mary's River, the latter, i. e., Windmill Point, being the point where St. Inigoes Creek empties into the river. The bed here is very thin, not exceeding 2 feet in thickness.

SAMPLE OF MARL FROM THE ST. MARY'S FORMATION TAKEN BETWEEN WINDMILL AND CHANCELLOR POINTS, ST. MARY'S COUNTY.

Silica (SiO_2)	35.12
Alumina (Al_2O_3)	2.28
Iron oxide (Fe_2O_3)	3.22
Lime (CaO)	29.14
Magnesia (MgO)	3.89
Ignition	26.31
Total	99.96

From the above analysis and from the thickness—less than 2 feet—of the bed from which this sample was taken, it is evident that it has no economic value whatever.

Many other localities besides those mentioned were examined in the hope that material would be found suitable in quality and quantity for the manufacture of Portland cement or for the manufacture of lime. The quest, however, was in vain. Some of the marl deposits may be used for making lime for local uses, but neither in the Miocene nor Eocene, nor in any of the formations of the Coastal Plain, are there known occurrences which are adapted for use in the manufacture of cement, because where the beds are satisfactory as regards chemical composition or quality there exist an insufficient quantity of material to justify the erection of a plant which would base its operations on its use.

The following analysis was made on a sample of the green marl occurring at Chesapeake Beach, taken about ½ mile south of the pier. It contains a little over 1 per cent. of lime, and is submitted here to show the chemical composition of this material, which in the past has been somewhat extensively employed as a fertilizer because of its content of phosphorus.

SAMPLE OF MIOCENE MARL FROM THE CALVERT FORMATION, CHESAPEAKE BEACH, CALVERT COUNTY.

Silica (SiO_2)	89.58
Alumina (Al_2O_3)	2.66
Iron oxide (Fe_2O_3)	1.88
Lime (CaO)	1.06
Magnesia (MgO)	.52
Phosphorus (P_2O_5)	.77
Ignition	3.63
Total	100.10

THE LIME AND CEMENT INDUSTRY IN MARYLAND.

INTRODUCTORY.

The materials in Maryland suitable for making lime and natural and Portland cements are widely distributed. The lime industry is already an important one. The total product in 1907 was valued at $344,316. A number of plants have also been built to manufacture natural cement, but their output has fallen off in recent years owing to the fact that Portland cement is rapidly replacing their product. One plant for the manufacture of Portland cement is in operation, and another, comprising facilities for the manufacture of both Portland cement and hydrated lime, is in process of erection.

A considerable proportion of the limestone quarried in the State is used for building purposes, road-making, ballast, or concrete. Limestone suitable for blast-furnace flux and for use in the open-hearth process of steel-making is also known to occur. The statistics on the production of limestone gathered by this Survey do not show how much has been quarried and sold exclusively for flux, and apparently the production for this purpose is small. Most of the limestone used for

flux at Sparrows Point is shipped from the vicinity of Martinsburg, West Virginia.

The total production of limestone for other purposes than the manufacture of lime and cement is given below. The figures show that the production has increased from an output valued at $13,801 in 1896, to an output valued at $142,825 in 1907. Another important fact brought out is the steady increase shown in the past eight years in the consumption of crushed limestone for ballast and for concrete work, the latter being one of the indications of the increased use, during the same period of time, of cements in construction work of all sorts.

Crushed stone for ballast and concrete is sold both by the ton and by the perch, the latter equalling about 2500 pounds. The prices quoted for broken and crushed limestone in Maryland ranges between 70 cents to $1.25 per perch, and from 60 cents to $1.00 per ton.

VALUE OF ANNUAL PRODUCTION OF LIMESTONE,† 1896-1908 IN MARYLAND.

	Building.	Flagging, curbing and paving.	Crushed—Road ballast and concrete.	Sold for flux and lime.	Miscellaneous—Rubble and riprap.	Total.
1896	*	*	*	*	*	$13,801
1897	*	*	*	*	*	16,924
1898	$10,768	*	$155,714	$3,446	$276	170,204
1899	8,896	*	7,292	869	647	17,703
1900	11,385	*	14,343	7,593	2,169	35,490
1901	14,138	$1,796	59,663	4,707	420	74,724
1902	16,953	1,575	95,966	9,097	3,022	126,613
1903	8,361	6,748	48,464	1,419	80	65,732
1904	12,836	1,036	111,147	2,466	902	128,387
1905	42,766	246	100,641	699	5,050	149,402
1906	8,393	779	160,109	*	765	170,046
1907	2,100	1,937	137,288	*	1,450	142,825
1908	13,105	150	114,405	210	721	128,591

† Exclusive of lime and cement.
* Statistics incomplete in detail.

THE LIME INDUSTRY.

The lime-making industry is at present by far the most important of the industries dependent on the use of Maryland limestone. The lime produced in 1905 reached the highest value, so far as Maryland is concerned, in the history of the industry, amounting to $360,247, or

over 2.4 times the value of the limestone reported for use for other purposes.

Lime production and the value of the total product, with the exception of comparatively small fluctuations, has been steadily increasing during the past 10 years. This may be seen by reference to the table below. The larger part of the product was used in liming land and most of the rest in construction work.

TABLE OF VALUE OF LIME PRODUCED ANNUALLY IN MARYLAND.

1896	$250,477
1897	182,441
1898	263,449
1899	217,522
1900	281,717
1901	307,657
1902	326,417
1903	320,494
1904	309,079
1905	360,247
1906	350,460
1907	344,316
1908	332,455

The greater part of the lime made in Maryland is obtained from burning limestone in the old-fashioned vertical, mixed-feed, continuous kiln, though some of the kilns employed are constructed along more modern lines. Better styles of kilns not only would effect a great saving in the cost of production, but would, at the same time, result in a much better commercial product. Continuous kilns, built of stone, are universally used in the larger plants. These, however, are being gradually supplanted, with the growth of the industry, by steel-clad kilns lined on the interior with the variety of fire-brick best adapted for that purpose. In the regions removed from transportation routes and where the demand is small, and lime is made only to supply the local demand, the more primitive intermittent kiln may, however, still be found in use.

Some of the larger plants in the State sell lime by the ton, but in most cases it is sold by the bushel—of 2150.42 cubic inches capacity.

The bushel, however, is estimated in practice by weight rather than by cubic inches. This varies from 70 to 90 pounds. The great majority of plants, however, report the bushel as weighing 80 pounds, and figure on 25 bushels of lime to the ton.

The price of lime in Maryland, as elsewhere, varies, of course, with the quality of the product. The lower grades of lime sell for from $7\frac{1}{2}$ to $9\frac{1}{2}$ cents, and the best grades that are manufactured near Baltimore at about 16 cents to the bushel. The range in price varies, therefore, from $7\frac{1}{2}$ to 16 cents per bushel f. o. b. at the point of shipment. The average price per bushel during 1907 was about 12 cents. The higher prices were obtained in the Texas-Cockeysville district, and the lower prices for the inferior grades of lime at standard plants, and for high-grade lime manufactured at points less accessible to the larger markets.

The fuels used in the lime kilns of Maryland consist chiefly of anthracite and semi-bituminous coal, the latter coming from the western section of the State. Charcoal and wood are also employed for burning, but to a more limited extent. Anthracite coal being on the whole lower in ash and volatile matter and having a higher calorific value than any one of the other fuels mentioned is, on this account, generally preferred. It is bought and burned in the form of pea-coal or anthracite siftings, 1 ton of which will burn about 125 bushels or 5 tons of lime, or, in other words, 1 ton of anthracite will decarbonate about 10 tons of limestone.

Roughly, the calorific value of 1 ton of anthracite is equal to $1\frac{1}{8}$ tons of coke, and 1 ton of coke is equal to about $1\frac{1}{3}$ tons of bituminous coal. Hence, 1 ton of bituminous coal is equivalent to about $\frac{2}{3}$ of a ton of anthracite coal, and will, therefore, calcine nearly 7 tons of limestone. But these figures stating the relative calorific value and efficiency of the three fuels mentioned involve several obvious errors. They were compiled from the reports received from Maryland limestone operators who, in reporting the fuel used, gave the sort of fuel used (but not its analysis), the cost, amount used, and also the output of the plant. Before reaching an accurate comparison of the anthracite, bituminous

coal and coke one must know, besides the lime output and gross cost of the fuel, something of the quality of the fuel and the character of the limestone used. The figures given above, therefore, are only approximate, but they show nevertheless that in general the value and efficiency of anthracite, coke, and bituminous coal for calcination of limestone is in the order named, and that as a mixed-feed fuel in the continuous kiln in this State they are generally preferred by the operators in the order just mentioned.

The outlay for fuel in the manufacture of lime amounts to from 4 to 6 cents a bushel. The fuel item thus reaches from 70 to 80 per cent. of the total cost, which ranges from 5½ to 7½ cents per bushel. With lime ranging in price from 10 to 16 cents for the better grades, and averaging about 12 cents per bushel, the lime operator, with good management, has a very fair margin of profit.

Lime is sold either as "lean" or "fat" lime, depending on the content of lime (CaO) and magnesia (MgO). Both varieties are made in Maryland. The "fat" or caustic limes are manufactured from burning limestone containing less than 10 per cent. of magnesia, while the "lean" or magnesian limes are made from limestones containing more than 10 per cent. of magnesia. The former or the high calcium, called also caustic limes, with the addition of water, slake more rapidly than the "lean" or magnesian limes, and also set more slowly. The fact that the magnesian limes in slaking emit less heat for a unit of time than the "caustic" limes, and moreover set more rapidly, cause them to be preferred in some lines of work to the "caustic" limes. In general, however, the "fat" or caustic lime is the variety most in demand.

THE PORTLAND AND NATURAL CEMENTS INDUSTRY.

Maryland possesses abundant materials for the manufacture of Portland cement, but, unfortunately, the competition with Portland cements, from which the Maryland natural cement industry has had to suffer, has come from neighboring states which, with the exception perhaps of Pennsylvania, are no better supplied with raw materials.

The cities of Baltimore and Washington together consume annually

about 1,200,000 barrels of Portland cement. The demands of other though smaller markets, which Portland cement plants located in Maryland might also control, because of their proximity, and the transportation facilities that this State affords, amounts to almost as much, making a total of about 2,500,000 barrels. Yet there is but a single plant built in Maryland and a second in course of construction, whereas there should be several, aggregating a daily capacity of 10,000 to 12,000 barrels. This backwardness in cement manufacture is due largely to a lack of information as to the State's resources in this respect, and also because only within the past year or so has the subject of the Portland cement resources of Maryland been at all systematically studied.

The natural cement industry throughout the United States, with the exception of the years 1897, 1898, and 1902 has shown each year a decrease in production compared with the year preceding. The industry in Maryland has been no exception. The production of natural and slag cements, which is given below, reached in 1896 a total of 250,000 barrels, valued at $115,000, but in the next 10 years the output steadily decreased until in 1906 the production amounted to 66,350 barrels, or a little more than one-fourth of the output reported for the first year of the decade, 1896-1906.

At the close of 1907 not one of the four Maryland natural cement plants or the one slag cement plant that had been constructed at Sparrows Point was in operation. The effect of closing down of these plants will, however, only be temporary. Their place in the industrial activity of the State will be more than occupied by the Portland cement industry; for the cessation of operation of the last of the natural cement plants in the fall of 1907 was followed by the construction of the first Portland cement plant to be built in Maryland, which began manufacturing in 1908. At the present time a second large Portland cement plant is being erected, while a hydrated-lime plant proposes to place its product on the market before this report is distributed.

It is safe to predict that other Portland cement plants will also be built, for Maryland is plentifully supplied with material which is well adapted for use in this industry.

TABLE OF PRODUCTION OF NATURAL AND SLAG CEMENTS PRODUCED IN MARYLAND.

	Barrels.	Average price.	Value.
1896	250,000	$0.46	$115,000
1897	200,000	.52	104,000
1898	307,475	.44	136,489
1899	372,000	.42	154,800
1900	343,070	.41	140,028
1901	358,329	.54	180,665
1902	423,200	.38	161,180
1903	279,957	.53	148,619
1904	70,000	.51	36,250
1905	61,324	.54	33,494
1906	66,350	.49	32,675
1907*	......	....	....
1908	......	....	....

* To give the figures for 1907 and 1908 would disclose the product of individual operators since three or more plants have not reported production during the year.

The cement plant constructed at Sparrows Point, the statistics of whose output are included in the foregoing table, is the only one in Maryland located east of the Blue Ridge. It was built in 1898, and was the second plant established in this country for the manufacture of slag cement.

Most, if not all, of the ores used in the furnaces at Sparrows Point come from foreign sources, the greater part of the tonnage being mined and shipped from Cuba. When the slag-cement plant was in operation these were fluxed chiefly with limestone, marble, and oyster shells, and the resulting slag was granulated and used in the manufacture of slag cement. The capacity of the works is 500 barrels a day. The cement manufactured by the Maryland Cement Company is reported as a non-staining puzzolan with an average specific gravity of 2.90+. The future successful operation of this mill, which is now closed, appears doubtful.

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